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Good Working Conditions in Nuclear Operation

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[Article by V. I. Smutnev, engineer]

[Text] Good working conditions in nuclear operation is not a reborn term and, moreover, is not a new concept. Without a doubt, good working conditions in nuclear operation arose and began to develop together with the appearance and development of the first nuclear reactors—first with research reactors, then with "provision" reactors, and finally with power-generating reactors. It is worth noting, however, that the development of good working conditions in nuclear operation had a perhaps somewhat unconscious, spontaneous, and dependent nature during the first two stages of the establishment of nuclear engineering and technology. Good working conditions in nuclear operation were not only dependent on the initial level of the development of nuclear engineering and technology and the degree of knowledge and understanding of the new physical processes during that period, but they were also greatly dependent on the objectives and tasks facing the new field of engineering at that moment. i.e., the creation of nuclear weaponry in the name of defense and even the survival of our socialist government. As in any military opposition, the priority of defense and the preservation of the government (which was intensified by the time factor) over the welfare of the individual personality was unconditional at the time. Even then, however, the fundamental bases of the working conditions of nuclear operation (which were later used during the transition to the third stage of the development of nuclear engineering and technology, i.e., power generation) had been laid.

It seemed as if the diametral shift in priorities during the third stage—the development of nuclear power generation—was made in order to increase the welfare of all of the people as well as each individual personality and that it should have nearly automatically led to the further conscious development and comprehension of the concept of good working conditions in nuclear operation, for this is the only path that guaranteed a real increase in welfare without the dramatic and even tragic failures that are possible when the terrible force of the atomic nucleus is underestimated. The paradox of this situation lies in the fact that it was precisely in this stage that the gradual "wiping out" of the previously laid foundations of good working conditions in nuclear operation began. In my view, two principal factors were responsible: the relatively successful assimilation of nuclear power generation technology during the period of its experimental commercial use and, consequently, the too-hurried transfer of the new technology to the long-evolved administrative structure of traditional power generation, which added a large number of different-level managers to the administration of nuclear power generation who simply had no concept of good working conditions in nuclear operation. The absence of the required special knowledge and the very foundations of good working conditions in nuclear operation forced these managers to consciously or unconsciously search for analogies in the familiar field of traditional power generation, drawing by no means unjustified parallels. It was precisely in this time, for example, that the popular opinion "A reactor is also a boiler" became widespread.

One of the main lessons of the events at Chernobyl is the need for a deliberate examination and analysis of the concept of good working conditions in nuclear operation that has evolved up until now as well as for the detailed development and use of this concept in the practice of operating power-generating units at AES in the strictest manner at all levels (and not just by operating personnel). This article attempts to identify and systematize those elements of the concept of good working conditions in nuclear operation that have naturally evolved and that have gradually been introduced into operating practice based on the 22-year experience of the operation of the power-generating units at the Novovoronezh AES.

I suggest that a detailed examination and analysis of the concept of good working conditions in nuclear operation as it has evolved up to the present moment should begin with a flowchart of the management of an AES power-generating unit—not by one operator (this was previously done in the "man-machine" context)[1] but rather in the overall structure of the management of power generation (Figure 1).

A first glance at this flowchart provides a justification for speaking about one of the basic axioms of the modern concept of good working conditions in nuclear operation—we have passed that stage where it was necessary to solely examine the problem of "man (operator)-machine" interaction. Quantity has grown into quality to the extent that on the first plane it is necessary to formulate the problem of "community-machine" interaction. The second axiom exists objectively from the very moment of the appearance of so complicated a system of very simple mechanisms that it can be called a machine. Any machine "knows" only the laws of physics and is completely "unaware" of the laws of human society: ideological concepts, accepted moral norms, hierarchical structure, and governmental laws. In this respect, the operator makes a connection between a specified human community and the machine on the basis of the maximum possible knowledge of the physical laws determining the operation of the given machine. The operator's "language of communication" with the machine consists of operating instructions and safety rules in which the operator's responses to possible "actions" by the machine are specified (the concept of the machine's "actions" refers, for example, to changes in the parameters of the production process). Flowcharts of the protections, controls, and instruments related to the parameters are the "communication" tools. And although the third axiom regarding good working conditions in nuclear operation should undoubtedly be that

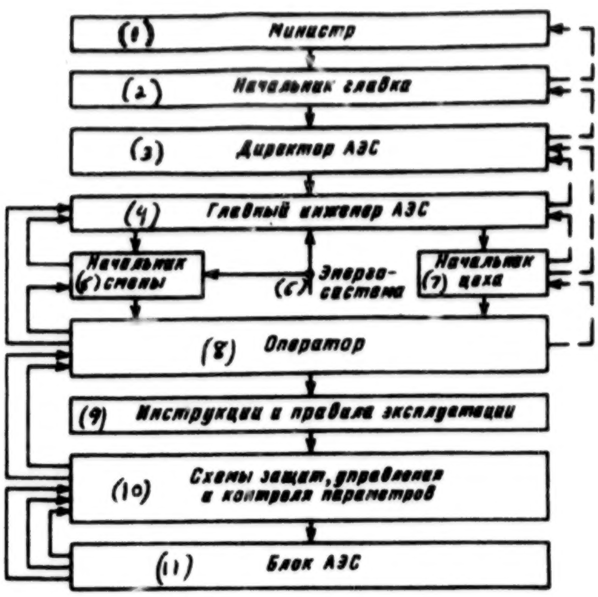

Figure 1.

Key: 1. Minister 2. Board head 3. Director of AES 4. Chief engineer of AES 5. Shift foreman 6. Power generation system 7. Shop foreman 8. Operator 9. Operating instructions and regulations 10. Flowcharts of protection, control, and monitoring of parameters 11. AES power-generating unit

any of the currently existing machines (including a power-generating unit at an AES) is an absolutely direct cause-and-effect system (the specified actions of an operator always correspond to the fully specified and unequivocal "action" of the machine), the instructions and rules that are used as the "language of communication" are always relative. This relativity reflects the relativity of our knowledge of those laws on whose bases machines have been designed and operate, and it constitutes the fourth axiom. Finally, the fifth axiom of good working conditions in nuclear operation is the significant objective indeterminacy of the hierarchical system controlling the community that interacts with the machine and, consequently, with the operator (the fact that the operator is an ordinary person must not be forgotten). Thus, at the current level of the development of science and technology, the concept of good working conditions in nuclear operation is defined by the six axioms.

1. A machine not only (and not solely) interacts with an operator but with a specified controlling community.

2. A machine does not and cannot "know" the laws of human society.

3. A machine is always an absolutely directly determined (cause-and-effect) system.

4. Operating instructions and rules are always relative (in proportion to the relativity of the knowledge of the laws of the machine's actions at the given moment).

5. The hierarchical structure of the controlling community that interacts with the machine is an objectively indeterminate system.

6. The operator is a human being with all of the physiological, mental, and social features of a human being in general.

All that remains to be added to these six axioms is a formula for mathematically estimating the quality of good working conditions in nuclear operation in one controlling community or another:

$K_{work\ cond} = \Sigma n_i^{corr} / \Sigma n_i$,

where n_i is a single action by an operator with respect to a machine and n_i^{corr} is a single correct action by an operator, i.e., an action resulting in the anticipated positive response to an action on the part of the machine.

In the ideal case when all of an operator's actions with regard to a machine that are taken after a rather large time interval are correct, $K_{work\ cond} = 1$. The closer $K_{work\ cond}$ is to 0, the poorer the working conditions related to nuclear operation in the given controlling society.

What interests us in this formula are the reasons why the quantity $\Sigma n_i - \Sigma n_i^{corr}$ exists and what it depends on, i.e., the sum of the operator's actions that do not fully or partially correspond to the laws governing the machine's action and leading (in accordance with axiom 3) to negative response actions by the machine. The answer to this question is no problem. The reasons are as follows:

the insufficiently complete and correct reflection in the operating instructions and rules of all of the laws governing a machine's action;

an insufficiently complete knowledge on the part of the operator of the operating instructions and rules because of subjective and objective reasons;

the nonoptimal physical and psychological status of the operator at the moment a given action is completed, which affects both the correctness and the timely completion of the given action; and

the presence of a signal—an order or an instruction—on the part of the controlling community that completely or partially contradicts the laws governing the machine's action.

But although there are no doubts as to the need to constantly improve the language of the operator's "communication" with the machine, i.e., the operating instructions and rules, attempts to attribute the incompleteness of an operator's knowledge of the instructions

and rules to solely subjective reasons (insufficiently wholehearted study) are more often than not encountered at the different levels of the controlling system. And it is by no means unselfish: the acknowledgment of the impossibility of an operator to fully remember several thousand pages of machine-written or printed text by ordinary reading due to the natural limitations of human memory (in accordance with axiom 6) would demand that the controlling community expend very great efforts to develop and introduce new methods of training an operator and maintaining his knowledge at the necessary level over time (the introduction of personal computers, the compilation of instructional computer programs, instruction, simulations, etc.). The situation regarding optimizing an operator's physical and psychological status during work is practically the same. Although verbally acknowledging the importance of this type of optimization, in the actual practice of their work, most managers at all levels of the control system do not even follow the elementary rules regarding maintaining the respective morale and psychological climate at operators' workstations. The following is a very simple example: the "blow-up" of a higher-level manager, even for truly erroneous actions on the part of an operator at the beginning of a shift, will throw the operator off balance to the extent that the correctness and timeliness of his actions in the event of accident situations during the course of his shift are virtually excluded. Obviously, it also follows that, up until now, lodgings have been distributed without any legislative or practical consideration of the distinctive features of the work done by operating personnel, i.e., their need to work at night and sleep during the day despite humans' sleepiness at night, which is the result of human evolution rather than the subjective negative qualities of an operator (in full conformity to axiom 6 of good working conditions in nuclear operation). And although severe penalties for sleeping at a workstation are undoubtedly necessary and justified, limiting things to such punishments alone once again confirms the lack of desire on the part of managers at other levels of the hierarchical structure of the controlling community to burden themselves with the additional work of looking for and introducing measures capable of even partially compensating for the objective features of the human organism.

However, all of the reasons examined for the erroneous or untimely action of an operator that cause negative response actions by the machine appear in singular cases and result in such negative consequences for the operator himself that he rarely repeats the same mistakes twice. The situation in which an operator receives signals—orders or instructions—from the controlling community that contradict the laws governing the machine's operation is entirely different. We are above all referring to the fact that, in accordance with axiom 3 of good working conditions in nuclear operation, feedback from a machine to an operator is absolutely direct (unlike the feedback between other elements of the hierarchical structure of the controlling community, which are determined not only by the laws governing the machine's actions but also largely by the laws governing human society). The higher the location of the element in the hierarchical structure, the greater the extent to which its actions are determined by the laws governing society and the lesser the extent to which the laws governing the machine are taken into account during these actions. As a consequence, the feedback to this element from the lower-ranking element and from the element itself to the higher-ranking element become increasing lesser (in full conformity with axiom 5 of the good working conditions in nuclear operation).

It would be possible to consider this type of change in the relationship of the laws governing society and the laws of physics in proportion to the movement up the hierarchical structure natural, provided that that necessary relationship that would make it possible for all of the community's control signals that do not contradict the machine's action to reach the operator was preserved. In actual reality, however, the necessary relationship at high levels of the hierarchical system is violated: first, on account of insufficient knowledge of the laws of physics and, second, on account of insufficiently direct feedback.

Insufficiently direct feedback results in a situation n which the signal (order, instruction) sent upward is not adequately corrected at the lower levels of the system where knowledge of the laws governing the machine's action is already entirely adequate to do so. At these levels, the necessary relationship between the laws of society and the laws of physics is violated in most cases not as a result of a lack of knowledge of the latter but rather because of a subjective absolutization of the laws of human society (not so much the written laws, but rather the contrary!) over the laws of physics, i.e., over the laws governing the machine's action. The ultimate expression of this absolutization of human laws in spite of axiom 2 of good working conditions in nuclear operation (which for years has served as a tool to "erode" and undermine the fundamental bases of the concept of good working conditions in nuclear operation) is the following widespread narrow-minded "wisdom": "the boss ordered it, the subordinate must carry it out." By observing this formula in practice, each lower-ranking element in the hierarchical structure of the controlling community transfers the signal it has received from the higher level without making the necessary corrections and compounding the necessity of doing so at the lower level (thereby using axiom 5 of good working conditions in nuclear operation). The true expression of the objective indeterminacy of the hierarchical structure of the controlling community is that each of its elements has the objective capability of subjectively solving the problem—of making the necessary correction in the signal received or not doing so. Objectively, only the very last element in the hierarchical structure—the operator—lacks this capability since he has direct feedback with an absolutely strictly determined system, i.e., the machine (the version in which the operator does not have an adequate knowledge of the laws governing the machine's

action and thus cannot estimate the degree of the nonconformity between the signal, i.e., order or instruction, received and this law is not examined in the given case).

After having received a signal in which the laws governing the machine's actions are contradicted to some degree, the operator first tries to correct it through feedback to the higher-ranking element of the hierarchical structure, for this feedback, which is "propped up" by the determinism of the machine, is significantly more direct that that at all other levels of the controlling community (this is also stated in the operator's duty manual, i.e., "Having received an erroneous order from a higher-ranking operator, the operator must inform the sender of the order's erroneousness."). Moreover, precisely to avoid transforming signals contradicting the laws governing a machine's actions into action, the operator also has feedback from higher levels of the controlling system (in accordance with the duty manual, an operator has a right to contact the chief engineer if the higher-ranking operator insists on the execution of an order that the lower-ranking operator feels is incorrect and a threat to the normal occurrence of the production process and moreover to the life and health of people or the integrity of the equipment). Obviously, however, all of this only makes sense when the lack of conformity between a signal and the laws governing a machine's operation has arisen because of an inadequate knowledge of these laws. If the reason for the discrepancy was a deliberate following of the "boss ordered it" formula, the operator's feedback will be completely blocked (especially since the operator's rights and responsibilities are only stated in his duty manual, whereas the higher-ranking level of the hierarchical system, having gotten the operator to follow the formula of the absolutization of the unwritten law of the hierarchical relationships without question, does not only act declaratively). Having thus discarded the possibility of the respective correction of the signal, we must examine the situation in which an operator is fully and completely aware that the signal he has received contradicts the laws governing the machine's actions and that the operator's every attempt to act in conformity with the signal received will therefore result in a very negative action on the part of the machine (in full conformity with axiom 3 of good working conditions in nuclear operation). In this type of situation, one can only image three versions of the operator's actions:

out of subjective considerations or under pressure from higher-ranking hierarchical levels, the operator accepts the formula of the absolutization of the hierarchical relationships and acts in accordance with the signal received, closing his eyes to the subsequent negative responses by the machine (as a rule, this occurs in the case where the operator assesses the degree of negativity of the machine's critical actions as insignificant);

attempting to find a compromise decision in the situation that has developed, the operator corrects the signal himself, directing his actions to the gray area of the existing operating instructions and regulations since he understands that this gray area has to have some (albeit unknown-sized) margin before the machine demonstrates an a fortiori negative response; or

the operator decides not to perform the action called for in the erroneous signal that he received (as a rule, this may occur when the operator assesses the degree of negativity of the machine's response as being very high, i.e., the failure of the primary equipment, a threat to human health and life).

We will analyze the operator's actions from the standpoints of their possible consequences. In the first case, if the operator's assessment that the degree of negativity of the machine's response actions would be insignificant was ultimately correct, the losses for all of society are not great. The machines will shut down, i.e., they will not produce up to capacity, there will be insignificant breakdowns of the auxiliary equipment, etc. In such situations, the operator and those individuals who are closest to him from the standpoint of the hierarchical structure of the controlling community generally bear the responsibility for the failure to carry out the existing operating instructions and regulations, which the controlling community itself forced the operator to violate. Another version is also possible. In this version the operator comes to grips with the machine's negative response action during the transient process since, during this time, he is acting not on the basis of the signals from the control system but only on the basis of his own knowledge of the laws governing the machine's action, in which case no one bears any responsibility for issuing or executing an erroneous order.

In the second case, if the probability of a negative response action on the part of the machine, including in the gray area of the operating instructions, is not materialized, the operator is reinforced in his opinion that some deviation from the existing operating instructions and regulations is completely acceptable. In the case where the probability of a negative response action by the machine in the gray area of the operating instructions and regulations does materialize, the situation corresponds to the first case.

In the third case, the operator acts in full conformity with the fundamental postulates of the good working conditions in nuclear operation, which are most fully expressed in the formulation "The operator of a reactor is justified in independently shutting down the reactor if he finds that its further operation would threaten the safety of the AES" (section 5.9 PBYa-04-74) or, in more categorical form, "To carry out orders contradicting the present Regulations is forbidden" (PTB, section 1.1.9). But since the operator did not perform an erroneous action, there are no obvious negative response actions by the machine. This makes it possible for advocates of the

absolutization of the principle of hierarchical relationships, i.e. "The boss ordered it," to speculatively assert that there could be no negative consequences and to punish the operator for his "unjustified failure to carry out an order."

Thus, in his practical activity, the operator is constantly "squeezed" between a strictly determined machine and the hierarchical superstructure of the controlling community, which absolutizes the unquestioning and unthinking subordination of the lower hierarchical levels to the high (which means the complete or almost complete absence of feedback in the system). This inevitably leads to the conclusion that it is possible and even necessary to keep one's actions in the gray area of the operating rules, i.e., to operate with constantly larger or smaller violations of these instructions and regulations.

The dialectic of a violation of the laws—the spontaneous exacerbation of the violations from the standpoint of quantity and quality—then comes into play. The relativity (probability) of actions based on the operating rules and regulations leading to the probability of a negative response action on the part of the machine increases as the number of violations increases, as the violations become more serious, or as an increasing number of violations are piled on top of one another until the violations become so numerous and frequent that the probability approaches 1. Because the operator perceives negative response actions by the machine that have insignificant consequences as confirmation of the acceptability of violating the operating instructions and regulations in their gray area, the Chernobyl tragedy was inevitable.

Conclusions

The theorems of the concept of good working conditions in nuclear operation are as follows:

1. The decisions that are made at any level of the hierarchical structure of the controlling community and that are signals for an action by an operator must make the necessary allowance for the laws governing the machine's action.

2. The feedback from each level of the hierarchical structure of the controlling community to the higher-ranking level should be sufficiently direct to allow the possibility of correcting the control signal passing through the level.

3. The control signal should reach the operator in a form that has been strictly corrected and that does not contradict the laws governing the machine's operation so as not to compel the operator to search for a compromise and act in the gray area of the operating instructions and regulations, i.e., to more or less violate them.

4. There should be a superstructure monitoring and correcting organ that directly cuts all incorrect signals off from reaching an operator.

5. Independent of the level on which they arise, signals reaching the operator that contradict the laws governing the machine's operation to any degree will result in a spontaneous exacerbation of the violations, both quantitatively and qualitatively.

6. The work of an operator in the gray area of the operating instructions and regulations will inevitably result in negative response actions on the part of the machine that are hazardous for all of human society.

Footnotes

1. Smutnev, V. I., Revin, A. V., and Yefryushkin, V. A., "Operator in AES Management System and Need to Optimize Data Base Management and Organization Supporting His Activity," ELEKTRICHESKIYE STANTSII, No 5, 1986.

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Using Programmable Simulators To Provide Antiaccident Training to Dispatch Personnel

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[Article by V. M. Gurychev, V. I. Kuklev, V. G. Ornov, and N. V. Stepanov, engineers, Central Dispatcher Administration of the USSR Unified Power Generation System under "Personnel Training" rubric: "Using Programmable Simulators To Provide Antiaccident Training to Dispatch Personnel"]

[Text] As the automation level of control over power generation systems and power generation associations and the operating reliability of their components increase, a reduction in the degree to which dispatch personnel are prepared to eliminate accident situations has been noted. Many dispatchers of the Central Dispatcher Administration of the USSR Unified Power Generation System and Centralized Dispatcher Administration who have worked for a rather long period of time have hardly taken part in eliminating serious accidents. Because of these facts (as not only the domestic but also the foreign experience indicate), in an accident situation a dispatcher may lose his head and not take quick and effective measures to eliminate the accident, which in turn may result in the further development of the accident and an increase of the economic damage resulting from its consequences.

Only the regular provision of antiaccident dispatcher simulations can reduce the likelihood of similar inauspicious situations. The effectiveness with which skills related to eliminating accidents are acquired is largely

dependent on how close the content and process of the training is to the real operating conditions of a dispatcher in accident situations.

At the present time, antiaccident dispatch training is conducted without using hardware in practically all centralized dispatcher administrations and power generation systems. Most of the time they are conversations between the person being trained and an inspector involving control paper diagrams of the network and power generation units being checked. Simulations are generally conditions at separate sites and more rarely at a dispatcher center so as not to interfere with the work of the existing dispatcher shift. In individual situations, telephone communications are used in the training process. When the training themes and scenarios are developed, a number of calculations that are necessary to assess the initial (preaccident) and postaccident conditions—and more rarely several intermediate and resultant conditions that may be achieved when the measures stipulated by the training scenario are implemented—are made. If an irregular situation arises during the training process, the inspector assesses the conditions without any exact quantitative calculations. It is entirely natural that such a method of conducting antiaccident simulations hardly facilitates the formation and reinforcement of accident elimination skills in dispatchers.

It should be noted that definite success has been achieved in domestic practice in the area of using simulators for the operating personnel at AES, TES, and electric power networks. These simulators, which have different degrees of completeness and complexity, are generally based on individual computer complexes and located in instruction and training centers and stations at power generation systems and electrical power network enterprises. At the same time, programmable simulators are being introduced very slowly at dispatcher stations of power generation systems and power generation associations that are well equipped with comparatively powerful information and computer systems. What is the reason for this lag?

The principal objective reason is that creating a full-scale dispatcher simulator (i.e., a complete simulation of a power generation system) requires significant computer resources commensurate with or perhaps equal to the resources of the existing online information and control complexes of the automated dispatcher control systems of power generation systems and power generation associations. Allocating individual computers for this purpose with an allowance for the real capabilities of delivering and acquiring them is virtually impossible to implement. The second objective reason is that creating a complete situation of a power generation system is a very complex and cumbersome task from a conceptual and technical standpoint and can only be accomplished after having solved the preceding problem. Moreover, the situation is even further exacerbated by the diversity of the types of computers used in power generation systems and at power generation associations.

Solving the problem in parts, i.e., creating one or several simplified models of a power generation system on the basis of an online information and control complex that would thus make it possible to model certain properties of a control object, is one obvious alternative that makes it possible to make an allowance for objective difficulties. These models may be made more complex and may eventually be integrated as online information and control complexes are modernized and as computer resources increase. Even in the first step, however, simplified models may be of great use in the process of conducting antiaccident simulations and will make it possible to accumulate practical experience with regard to using programmable simulators and methods of developing training scenarios—something that is of no small importance. They will also make it possible to determine the most feasible ways of developing programmable simulators.

Included among the subjective reasons holding back the creating and introduction of programmable simulators is the passive (and in a number of cases, negative) attitude toward this problem on the part of operating and dispatch personnel and dispatch service directors. Experienced dispatchers most commonly use an all-or-nothing justification: an absolutely complete model is necessary, simpler models cannot teach us anything new. There are hidden motives as well, including the "student syndrome" (dislike of formalized control on the part of the computer), fear of possible errors while working with computer technology, a lack of capability of certain conventions during interaction and information representation, etc. The virtual absence of domestic specialists in dispatcher services whose job it would be to remedy the problems in creating and introducing simulators and training systems, check the knowledge of dispatch personnel, and continually track and improve these systems is one of the main reasons. It should be considered that the more complete the model of a power generation system used in a simulator, the greater the amount of work involved in monitoring the model and maintaining it in an up-to-date state.

Despite the aforementioned facts, work to create programmable simulators for operating and dispatch personnel at power generation systems and power generation associations was begun back at the end of the 1970's. In view of the limited resources used in the online information and control complexes of computers as well as the foreign experience, it was decided to create no one "full-scale" simulator but rather two functional groups—mode simulators and routine switching simulators.1 Mode simulators are intended to help a dispatcher acquire the skills to maintain the parameters of a power generation system's mode within a specified (allowable) range during unplanned and accident disruptions in the active power balance as well as during changes in the network's circuit. This category of simulators is above all necessary for those dispatchers at higher management levels (the Central Dispatcher Administration of the USSR Unified Power Generation

System, the Centralized Dispatcher Administration, large power generation systems). Routine switching simulators are intended to help in the acquisition of the skills entailed in performing switching operations in distributing devices at electric power plants and substations during normal and accident situations. These simulators are above all useful at lower management levels (power generation systems, electrical networks).

Within the framework of this concept, in 1979 a very simple pseudodynamic mode simulator for a dispatcher of the Central Dispatcher Administration of the USSR Unified Power Generation System was developed on the basis of a Videoton-1010B type minicomputer online information and control complex. It simulates a mode from the standpoint of frequency and active power for a radial eight-node circuit of the USSR Unified Power Generation System.[2] The initial parameters of the active power balance of each of the 8 individual power generation systems (up to 12 time points) were entered when the computer simulations were prepared. After the model was started up, the mode was "twisted around" in an accelerated time scale with linear extrapolation of the balance parameters in the time intervals in between, and disturbances such as injections of power in the nodes or switchings of the network circuits could be added to the initial mode. A display was used to monitor and control the mode.

In 1981 a universal adaptive routine switching simulator was developed on the basis of a YeS-1011 minicomputer[3] that made it possible to monitor the correctness of the performance of switchings in the distributing devices of one or more interconnected substations. The adaptability of the simulator lies in the fact that the switching rules were unified and not dependent on the scenarios of the simulations and circuits being modeled. This made it possible to create a library of the diverse circuits used in different simulators. In recent years this simulator was modified for an CM-4 (CM-1420) minicomputer and for YeS computers.

A mode simulator based on the online information and control complex of a YeS computer was introduced at the Central Dispatcher Administration of the USSR Unified Power Generation System in 1983.[4] It was distinguished by the following:

complete automation of the input of the initial mode into the model based on telemeasurements entered into and stored in the files of the online information and control complex:

the capability of modeling a circuit with a random configuration;

use of a direct current computational model (calculation of a steady-state mode based on frequency and active power);

supplementation of the simulator with an antiaccident automation model, etc.

Unlike a static mode simulator, which makes it possible to model a postaccident steady-state mode arising under the effect of one type of disturbance or another, a dynamic mode simulator was developed for the SM-4 minicomputer in 1984.5 This simulator makes it simpler to model the dynamics of the parameters of a power generation system's mode (frequency, transfers of active power, electrical transmission phase angles). Static mode simulator using a direct current model were developed for YeS computers at the Leningrad Rayon Power Generation Administration and Centralized Dispatcher Administration of Siberia.[6,7]

The mode simulator that is the most advanced and developed from a functional and service standpoint is the one that was developed and introduced in 1985 on the basis of the minicomputer that is part of the online information and control complex of the Central Dispatcher Administration of the USSR Unified Power Generation System. Like preceding mode simulators, it is based on a direct current model, it includes an antiaccident automation model, its design circuit may include up to 132 nodes and 250 branches, and it uses color pseudographic displays for interaction. The mode simulator's program complex is included in the online information and control complex as one of the jobs, it uses the complex's information base, and it is constantly ready for operation. This mode simulator was been continually developed and improved during the process of its operation until by the end of 1988 plans were formulated to perfect a pseudodynamic version and to eventually attempt to connect the mode simulator with the elements of a routine switching simulator. Unfortunately, subjective factors have kept the specified developments from becoming widespread in operation, the only exceptions being two of the aforementioned mode simulators at the Central Dispatcher Administration of the USSR Unified Power Generation System (based on an KS-1011 minicomputer) and at the Siberia Centralized Dispatcher Administration (based on a YeS computer).

We will examine several aspects of the organizational and methodological support for the preparation and conduct of dispatch personnel training when using a mode simulator connected to the online information and control complex of the Central Dispatcher Administration of the USSR Unified Power Generation System. The model for calculating a steady-state mode includes the design scheme for the main network of the USSR Unified Power Generation System (64 nodes, 128 branches) in which all of the overhead lines under the control and management of the dispatcher and the remaining elements of the circuit are represented by equivalents. At the dispatcher's request, telemeasurements of the parameters of the current or a retrospective mode (the values of the frequencies, transfers of active power along the overhead lines and cross sections, power

of certain electric power plants, coefficients of the constant-error responses of the circuit's nodes, and maximum allowable limits of transmitted power) are input into the model. The initial, resultant, or incremental mode may be examined in the general circuit of the USSR Unified Power Generation System or in three separate, more detailed fragments, as well as in tabular form on the screens of pseudographic displays. Emergency disturbances are input by using a display keyboard through tables of nodes or lines with their dispatcher names (the connection or disconnection of lines is entered through a line table, and the value of the active power dysbalance is entered through a node table). The resultant (postaccident) mode may be calculated with or without an allowance for the preventive automation equipment (the automation equipment to prevent a disruption in stability, automation equipment to eliminate an asynchronous mode, and automated frequency discharge). After the start-up and completion of the calculation (10 to 15 s), an overall diagram of the Unified Power Generation System corresponding to the postaccident mode is output onto a display screen. A dynamically formulated table of the devices activated with an indication of the amounts of offswitched load or generation is output during the operation of the preventive automation equipment. The service portion of the mode simulator is rather universal and makes it possible to adjust the model of the network and preventive automation equipment for a specific control object (within the framework of the software environment of a YeS-1011 computer). Implementing a mode simulator on the basis of a computer's online information and control complex makes it possible to use any displays connected to the online information and control complex's minicomputer for the simulations, including those at the workstation of the dispatcher on duty. However, simulations are conducted at specially allocated sites (so as not to distract the working shift from controlling the mode), whereas a dispatcher may use a mode simulator at his workstation for training or to model anticipated modes, analyze requests, etc. Two isolated sites equipped with displays of the computer's online information and control complex and telephone concentrators to organize direct communications between both sites (up to three channels) with the capability of output to a dispatcher telephone switchboard (used when organizing multilevel training) are provided. A shift of trainee dispatchers and one tester are generally located at one site. Located at the other site are the training manager and his assistant, who simulates accident situations during the training process and gives assignments to the trainee dispatchers with regard to controlling the mode.

Selecting a theme and developing a training program (scenario) is one of the most important phases of preparing antiaccident training. This is usually done by the dispatch service director and dispatch service personnel. The theme is often selected on the basis of some actual operating situation that might lead to the occurrence or development of an accident as the result of one or more exacerbating circumstances (a sudden shortage of generated power, the failure of relay protection or antiaccident automation equipment, the failure of switching equipment, a fire at the power generation facility, an emergency announcement to repair equipment, etc.). The mode simulator, which makes it possible to quickly and easily play out a set of modes and select the one that is most suitable for the basic trajectory of respectively complex events, can be of great help during the process of the development of a scenario. It is advisable that a dispatcher have several alternative routes when restoring a mode. It is also important that several distracting events that increase the intensity of the circumstances be stipulated in the scenario against the background of the main events.

In the general case, the structure of the training may be represented in the form of a table specifying the main training steps, the actions of the trainee dispatchers and the individuals providing the training, and the hardware and other equipment used during the training process.

Before the training begins, in accordance with the prepared scenario, the trainer uses the respective instructions to input the initial mode into the mode simulator's model from the files of telemeasurements in the online information and control complex and informs the trainee dispatchers that the training is beginning. Having called a diagram of the network and its fragments up onto the screen of their display, the trainees analyze the initial mode and obtain additional information from the trainer. When necessary, they can examine certain display forms (tables, diagrams) existing in the computer's online information and control complex and corresponding to the initial mode stored in the files.

In the second step, the trainer can gradually make the mode more difficult, for example, by simulating a change in load in several of the network's nodes by disconnecting one piece of equipment or another, etc. After receiving messages from the trainer regarding the change in mode, the trainee observes them on the display screen, analyzes them, and (if he considers it necessary) can instruct the trainer to change the generation of one electric power plant (or region) or another. The trainer quickly carries out this instruction in the mode simulator model and confirms its execution on the telephone. The trainee can also monitor it on the screen of his display.

In the third step the trainer simulates the stipulated accident scenario (the emergency disconnection of one or several electric power lines or power-generating units or the division of the centralized power generation system into asynchronously operating parts, etc.). Both the correct and incorrect action of the preventive automation equipment may be simulated.

In the fourth step, the trainer instructs the trainees by phone to call a diagram of the postaccident mode up onto his display screen and simulates a message by duty

personnel from the Centralized Dispatcher Administration and power generation facilities regarding the accident events. The trainees analyze the postaccident mode, decide upon a strategy and tactics to eliminate the consequences of the accident situation, and distribute the functions among themselves (provided several dispatchers are participating in the training).

The fifth and sixth steps may be carried out in sequence or parallel with one another depending on the specific situations and decisions of the trainee dispatchers. Instructions to change the mode (in particular, the frequency, the transfer of power, and the connections and disconnections of the electric power lines) are sent by the trainee dispatchers by telephone to the trainer, who acts as the duty personnel of the Centralized Dispatcher Administration and power generation facilities, and are execution by the trainer with the help of the mode simulator. The trainee dispatchers use a display to monitor the execution. Since the topological model of the mode simulator only makes it possible to switch the electric power lines (the branches of the design scheme) and does not contain detailed diagrams of the power generation facilities, all measures related to analyzing these diagrams, switching the switching equipment, and I/O of the automation equipment and relay protection are conducted by using traditional diagrams of the power generation facilities that have been prepared on paper carriers. Instructions for the necessary switchings and messages about their execution are sent by telephone between the trainee dispatchers and the trainers, with the trainers making the connection or disconnection of the electric power lines as a whole in the mode simulator's model at the respective point in time.

In principle, the training may be completed after the sixth step; however, a seventh step may be conducted. This step is geared toward restoring the normal mode (if a more grave mode persists after the fifth and sixth steps).

It is evident from Table 1 that using a mode simulator is advisable in virtually all of the steps (even in the sixth). Mode simulators are most effectively used in the fifth step. Here it is important to note that the "game" foundation of the mode simulator allows different versions of behavior on the part of both the trainee dispatchers and the trainers, with the previously prepared scenarios playing the role of a training "outline" and the development of the consequences of the accident situation being able to proceed along courses that have not been previously stipulated. Cases are thus possible in which, while bringing the postaccident mode into an acceptable range, the dispatcher makes an error that leads to the activation of one piece of antiaccident equipment or another or to the disconnection of equipment, which in turn results in a new postaccident mode that was not analyzed when the scenario was developed. In the absence of a mode simulator, this situation may not be noticed by the trainer, or (if he does notice it) the postaccident mode may be assessed only qualitatively. In the first case, the dispatcher's error will not be taken into account during the assessment; in the second case, the training will in all likelihood be concluded prematurely. After the use of a mode simulator, the next postaccident mode will be represented on the display screen, and the dispatcher can continue to search for ways of bringing the mode into an acceptable range.

Table 1.

	Actions of Trainee Dispatchers				Actions of Trainers		
Training Stage	Monitoring and Analysis of Network's Circuit and Mode	Monitoring and Analysis of Power Generation Facilities' Circuits	Development and Issuance of Control Instructions Related to Changing Mode and Switching at Power Generation Facility	Reception of Messages From Duty Personnel at Lower Management Levels	Modeling Disturbances	Execution of Control Instructions	Messages to Dispatcher From Duty Personnel at Lower Management Levels
Initial mode	+	-	-	-	-	-	-
Initial mode becomes more grave	+	-	+/-	-	+/-	+/-	-
Accident	-	-	-	-	+	-	-
Postaccident mode	+	-	-	+	-	-	-

Mode is brought into acceptable range	+	+	+	+/-	-	+	+/-
Circuit restored, equipment at power generation facilities switched on, etc.	+/-	+	+	+/-	-	-	+/-
Normal mode restored	+	-	+	+/-	-	+	+/-
Equipment used	Mode simulator	Diagrams of power generation facilities	Telephone	Telephone	Mode simulator	Mode simulator	Telephone

As an example we will examine two scenarios at the Central Dispatcher Administration of the USSR Unified Power Generation System.

It is nighttime, and the USSR Unified Power Generation System is operating at an increased frequency. An emergency discharge of 2,000 MW from a high-power TES is made to the eastern part of the Unified Power Generation System, at which a shortage exists. Because of the overload of the highly loaded West-East cross section and the failure of the automation equipment intended to prevent a disturbance in stability, the automation equipment to eliminate an asynchronous mode is activated and the USSR Unified Power Generation System is divided into asynchronously operating western and eastern parts. After the operation of the automated frequency discharge in the eastern portion, the frequency is established at a level of 49.0 Hz, and a number of electric power lines are overloaded. In the western portion, the frequency increases to 50.45 Hz, and the transfer of power along a number of lines reaches emergency limits. The actions of the trainee dispatcher should be aimed at making a very quick change and equalizing the frequencies of the divided portions of the USSR Unified Power Generation System, discharging the dangerously overloaded electric power lines, and then connecting the asynchronously operated portions for parallel operation. During the process of eliminating the consequences of the accident, the dispatcher must do the following: correctly assess the constant-error response with regard to frequency and the regulating resources of the eastern and western portions of the unified power generation system, select those regulation objects that make it possible to simultaneously bring the mode into the required range from the standpoint of frequency and transfers of current without allowing any additional activations of the antiaccident automation equipment, prepare the necessary instructions with regard to switching the power generation units at the TES and restoring the feed to disconnected users, and make a correct allowance for the time factor when selecting mode measures (the beginning morning increase in load in the East and the anticipated morning increase in load in the West). This training is virtually completely conducted by using a mode simulator, and considering the multiple versions of restoring the normal mode, it cannot be qualitatively conducted without using a mode simulator.

The second scenario stipulates the accidental disconnection of four 500-kW overhead lines that extend to the buses of a high-power TES and that are a highly loaded transit between the northern and southern regions of the European portion of the USSR Unified Power Generation System. Because of the failure of the relay protection at the TES, the overhead lines were disconnected at opposite sides with respect to the TES. Under the effect of the antiaccident and station automation equipment, three units at the TES were disconnected and the automatic load cutoff system operated. In the postaccident mode the 500-kW buses of the TES were deenergized, the frequency in the USSR Unified Power Generation System was reduced 0.1 Hz, and one of the West-South transits became overloaded. The trainee dispatcher had to determine a way of quickly discharging the transit and raising the frequency, handling the situation at the TES and taking measures to restore its circuit and mode, and connecting the users disconnected by the emergency load cutoff system. The mode simulator is used most intensively during unloading of the transit and restoration of the frequency (there are several versions with varying degrees of effectiveness) as well as in the final stage—restoration of feed to the users who had been disconnected and fueling of the TES power generation units. The situation at the TES was analyzed, and the normal circuit was restored without using a mode simulator but by using detailed diagrams of the TES and its adjacent substations.

In conclusion it is appropriate to mention that, besides the purposes examined here, mode simulators can also be used by dispatchers or specialists in mode services for various types of express calculations related to assessing the active power flux distribution (assessment of the control actions stipulated by the dispatcher, analysis of the admissibility of permitting the emergency requests, retrospective modeling of accidents that have occurred) as well as for self-instruction by young specialists. Furthermore, the computational model and the mode simulator's other software modules serve as a consultative program to the dispatcher in bringing the mode to an admissible range.9 Besides serving its main purpose, this program may also be useful during the self-instruction and simulation process for comparing the decisions made by a dispatcher with those recommended in the consultative program.

Conclusions

1. Ensuring that dispatch and operating personnel are adequately trained to eliminate the consequences of accidents in power generation systems and at power generation associations is only possible with the systematic conduct of antiaccident simulations, the effectiveness of which is large dependent on the use of programmable simulators during the process of the preparation and conduct of the simulations.

2. It is advisable to implement programmable simulators on the basis of computers and other online information and control complex hardware, which makes it possible to provide a high degree of automation of the formulation of an information model of the power generation system, approximate the conditions under which training is conducted to the real conditions under which a dispatcher works from the standpoint of hardware and interaction methods and information display, and use the simulator's information model to perform other online management tasks.

3. In view of the limited computer resources of a computer online information and control complex, during the first step of introducing simulators it is advisable to use simplified models of a power generation system that implement one group of functions or another, in particular, mode simulators and routine switching simulators. As the computer resources of a computer online information and control complex increase, it is possible to expect that these models will be integrated and become more complex.

4. A mode simulator implemented on the basis of a YeS-1011 minicomputer of the online information and control complex of the Central Dispatcher Administration of the USSR Unified Power Generation System is being used successfully to prepare and conduct antiaccident training for dispatcher personnel and may be easily adapted for power generation systems and power generation associations that use analogous computers.

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Organizing Management of Classification Systems at Enterprises of USSR Ministry of Power and Electrification

18610334c Moscow ELEKTRICHESKIYE STANTSII in Russian No 1, Jan 89 pp 24-28

[Article by A. N. Super and I. S. Yavnykh, engineers]

[Text] Automating production management, including that of electrical power generation, is one of the most important directions of the economic and social development of the USSR in the 12th Five-Year-Plan and in the long-range future.

The use of different types of automated management systems at all management levels in electrical power generation requires constantly increasing the speed with which information is collected, sent, and displayed; increasing the automation level of the processes used in information processing; and increasing the quality with which information is stored and managed.

The wide-scale introduction of computer technology into different administrative nodes of the electrical power generation sector has made it necessary to bring the system of technical and economic information into full conformity with the requirements that have been imposed by modern methods of machine data processing in the computer center of an automated management system at all levels. In this context, the data base management and organization of the automated management system (which is understood to mean all of the following as a set: Unified System of Classification and Coding of Technical and Economic Information, the Unified System of Documentation, and the information files used in the automated management system) becomes very important.

The Unified System of Classification and Coding of Technical and Economic Information is one of the main tasks in the area of improving the system of technical and economic information and ensuring the information unity of an automated management system at different levels.

The Unified System of Classification and Coding of Technical and Economic Information consists of a set of interlinked systems of classifying technical and economic information; systems for managing them; scientific methodological and normative and technical documents for developing, managing, and introducing them; and organizations and services working to classify and code information.

The Unified System of Classification and Coding of Technical and Economic Information establishes the composition and content of works to classify and code technical and economic information and provides a standard procedure for planning and conducting this type of work throughout the country. The main goal of creating the Unified System of Classification and Coding of Technical and Economic Information was to standardize the data base management and organization related to the processes entailed in managing the national economy based on using computer technology.[1]

The following are the tasks of the Unified System of Classification and Coding of Technical and Economic Information:

ordering, standardizing, classifying, and coding technical and economic information in systems for managing the national economy;

ensuring the conditions for automating information processing processes, including creating automated data banks;

ensuring the information compatibility of interacting automated systems for managing the national economy and increasing the effectiveness with which they function;

ensuring methodological unity in the area of developing, introducing, and managing systems for classifying technical and economic information and unified documentation systems;

creating a complex of interlinked systems for classifying technical and economic information from various spheres and at different levels of using and organizing their management.

About 1,000 classification systems belonging to different categories (25 all-union, 150 sectorial or departmental, and about 800 local or enterprise classification systems) are used in the organizations and enterprises of the USSR Ministry of Power and Electrification. In total volume, these classification systems contain about 1.5 million positions. The largest (85 percent of the information contained in all the classification systems) and, accordingly, the most complicated from the standpoint of management is the All-Union System of Classifying Industrial and Agricultural Production.

Since the system of managing different categories of classification systems at the enterprises of the USSR Ministry of Power and Electrification is practically identical with a very small exception, the problems entailed in organizing their management are described by way of the example of the most complicated of the systems, i.e., the All-Union System of Classifying Industrial and Agricultural Production.

Using the information contained in the classification systems at the USSR Ministry of Power and Electrification has resulted in the following:

interbranch information exchange is improving and becoming faster;

the physical accounting of the traffic of commodity stocks is improving qualitatively;

the supply of materials and equipment to enterprises in the sector (the allocation of materials and assets to manufacture products) is becoming easier; and

the tasks entailed in personnel accounting, bookkeeping, production planning, repairing power generation equipment, distributing electric power to users, etc., are being accomplished.

Under modern conditions, the sphere of use of systems for classifying technical and economic information extends beyond the framework of automated management systems. For example, the All-Union System of Classifying Industrial and Agricultural Production must not only be used by the automated management system but also by all of the enterprise's subdepartments that participate in the process of developing, producing, and marketing products.

It is as if the All-Union System of Classifying Industrial and Agricultural Production code is a product quality document that ensures the product's conformity with all-union and world standards.

Unless a newly manufactured product bears the all-union code of the Unified System of Classification and Coding of Technical and Economic Information, its standards and specifications are not registered with the USSR Gosstandart's All-Union Information Fund of Standards and Specifications, the USSR State Committee on Prices does not confirm its optimum prices, the USSR State Committee for Material and Technical Supply does not allocate the material and technical resources required to produce it, and the Gosstandart forbids the sale of products without All-Union System of Classifying Industrial and Agricultural Production codes on their accompanying documents. The USSR State Committee on Statistics does not accept the accountability, statistical, and bookkeeping forms of documents without enterprise, ministerial, and territorial codes and other necessary marks.

By order No. 87 of the USSR Ministry of Power and Electrification from 10 February 1983, all organizations that are the developers of design documents are obliged to enter four-place letter codes in them.

The technical and economic information contained in the different classification systems is constantly subjected to specified changes. The changes may be periodic (related to the calendar obsolescence of information about facilities) or random (related to unforeseen changes in the process of the functioning of both the administrative facilitates and the classification objects). In accordance with these changes, the classification systems must be corrected completely and in a timely manner, i.e., they must constantly be kept in working (actualized) order.

Each year, about 15 to 20 percent of the information included in the systems for classifying technical and economic information (especially in the All-Union System of Classifying Industrial and Agricultural Production) undergoes a change. Obviously, the quantity of information circulated in the classification systems and their files cannot be kept in an actualized state without the use of high-speed computers and a specially created system for managing them.

In view of the importance of the work related to the Unified System of Classification and Coding of Technical and Economic Information, based on GOST 6.01.1-87, the "Unified System of Classification and Coding of Technical and Economic Information," the USSR Ministry of Power and Electrification specified the organizational structure of an automated system for managing all-union and sectorial (departmental) systems for classifying technical and economic information that was intended to update the information in classification systems and their files.

The system for managing the Unified System of Classification and Coding of Technical and Economic Information is a set of elements organized on the basis of a specified structure with a definite flow diagram for processing and exchanging information.

The system for managing technical and economic information classification systems in the USSR Ministry of Power and Electrification consists of the following elements:

a head organization for systems for managing classification systems in the sector based on methodological and organizational management of the development and introduction of a system for managing sectorial (departmental) systems of classifying technical and economic information;

base organizations concerned with standardization;

base organizations concerned with standardization that are responsible for managing the individual groupings and sections of the All-Union System of Classifying Industrial and Agricultural Production that are attached to the USSR Ministry of Power and Electrification;

leading organizations created on the basis of territorial and administrative features;

user organizations;

documents for managing the system; and

flowsheets for processing and managing the information fitted in the management system.[2]

The following are the main functions of the links of the system for managing the Unified System of Classification and Coding of Technical and Economic Information:

1. The head organization does the following:

provides methodological and organizational direction of the development and introduction of a sectorial automated system for centralized management of classification systems;

formulates and manages the fund of the sectorial (departmental) systems of classifying technical and economic information;

furnishes the leading organizations with typeset publications of the classification systems along with revisions and additions to them;

furnishes the sector's enterprises and organizations with the necessary instructive and methodological materials, information files, and sets of programs for managing the classification systems;

organizes interactions with the ministries that develop the classes of the All-Union System of Classifying Industrial and Agricultural Production in order to obtain information about changes related to the classes of the All-Union System of Classifying Industrial and Agricultural Production attached to them (approximately 70 ministries);

develops instructive and methodological materials related to managing the classification systems in the organizations of the USSR Ministry of Power and Electrification; and

implements sectorial monitoring of the introduction and management of the sectorial (departmental) systems of classifying technical and economic information in the leading organizations and their users.

2. The leading organizations do the following:

furnish user organizations and enterprises with instructive and methodological materials, information files, and program sets obtained from the head organization of the system for managing classification systems in the sector;

periodically report on changes in the classification systems by preparing, publishing, and sending out collections of revisions or notifications of revisions;

respond to user queries; and

manage check copies of the classification systems and their files, the information of which is used at user enterprises.

3. The user organizations do the following:

manage working copies of the classification systems and their files (rayon power generation administrations);

develop and manage files of special product nomenclature for their own enterprise;

refer queries regarding individual classification systems and samples or codes from these classification systems to their leading organization; and

furnish information from the classification systems to the subdepartments of their own organization (Figure 1).

By order of the USSR Ministry of Power and Electrification, the Production Association for Setting up and Improving the Technology and Operation of Electric Power Plants and Networks [Soyuztekhenergo] is the sector's head organization with regard to the system for managing the sectorial (departmental) systems of classifying technical and economic information.

The respective directive documents of the USSR Ministry of Power and Electrification designated a number of very large rayon power generation administrations that are well equipped with computer technology and that have trained specialists at their disposal as the leading organizations of the system for managing sectorial (departmental) systems of classifying technical and economic information. The automated organizational system for managing classification systems in electric power generation encompassed virtually all of the country's regions. The necessary instructive and methodological materials regarding creating and managing the files of sectorial (departmental) systems of classifying technical and economic information were developed and approved by the administration of the USSR Ministry of Power and Electrification, coordinated with the Gosstandart, and sent to all of the system's links. A unified software complex was developed for the system to manage the classification systems in the Unified System [YeS] operating system that makes it possible to regularly exchange information regarding revisions both within the sector and with the head organizations of other ministries and departments.

The system has been activated, has passed its pilot introduction period, and has been accepted by the Gosstandart into commercial operation, virtually without comments.

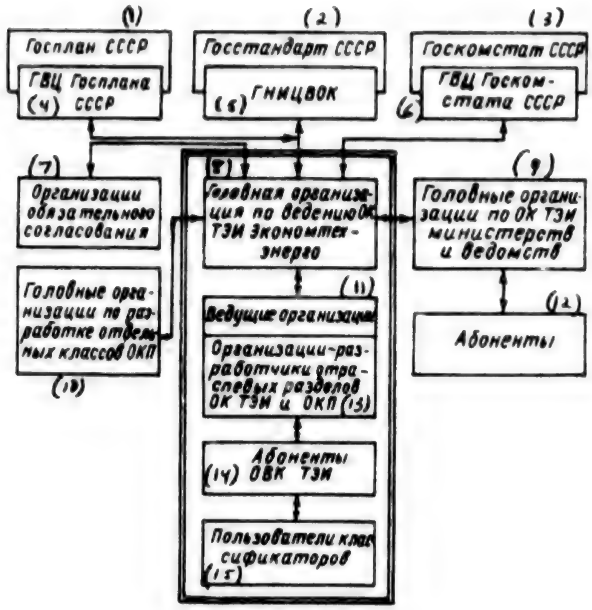

Figure 1.

Key: 1. USSR Gosplan 2. USSR Gosstandart 3. USSR State Committee on Statistics 4. Main computer center of USSR Gosplan 5. Main Scientific Research Center for Managing All-Union Classification Systems 6. Main computer center of USSR State Committee on Statistics 7. Organizations for mandatory coordination 8. Head organization with respect to managing Unionwide Classifier of Technical and Economic Information of the Ekonomtekhenergo 9. Head organizations with respect to Unionwide Classifier of Technical and Economic Information of ministries and departments 10. Head organizations with regard to developing individual classes of All-Union System of Classifying Industrial and Agricultural Production 11. Leading organizations 12. Users 13. Organizations developing sectorial sections of Unionwide Classifier of Technical and Economic Information and All-Union System of Classifying Industrial and Agricultural Production 14. Users of sectorial (departmental) systems for classifying technical and economic information 15. Users of classification systems

During the 3 to 5 years that have elapsed, however, the organizational system has begun to have soft failures, the information exchange has become irregular, and the files stored in the sectorial (departmental) systems of classifying technical and economic information have lost their guaranteed reliability.

The codes of the All-Union System of Classifying Industrial and Agricultural Production, which are so necessary to the material and technical provision of the sector's enterprises and organizations and to interbranch exchange, have not been taken from the files in their full nomenclature.

Correcting the situations that have developed in each specific case has necessitated a significant increase in expenditures of manual labor and time to retrieve the required information.

Unfortunately, it may be stated that the system for the centralized management of classification systems is not at present fully meeting the requirements established by GOST 6.01.1-87.

The factors negatively affecting the normal process of the functioning of the sectorial automated system for the centralized management of classification systems of the USSR Ministry of Power and Electrification may, in our view, be summarized as follows:

1. The structure of the system for managing the sectorial (departmental) systems of classifying technical and economic information has completely encompassed only electric power generation and does not touch construction, planning institutes, or the construction industry. Despite numerous reminders from the head organization of the system for managing classification systems in the sector, the industrial and construction boards have declined to designate leading organizations with regard to their own enterprises, without which it is impossible to implement the functions of managing the sectorial (departmental) systems of classifying technical and economic information at board enterprises.

Hundreds of letters from enterprises requesting assistance in finding or assimilating the individual codes of the Unionwide Classifier of Technical and Economic Information have been sent to the head organization. In individual cases, this assistance has been provided (in violation of the All-Union State Standards regarding the system for managing and assimilating code); however, completely satisfying the needs of all enterprises is technically impossible, even if the head organization with respect to managing classification systems in the sector disregards its main duties in order to do so.

2. Individual leading organizations of the electric power generation sector are not completely fulfilling their designated functions with regard to maintaining the files of the sectorial (departmental) systems of classifying technical and economic information in an actualized state and providing user enterprises with the necessary information. These organizations include the Voronezh, Leningrad, and Khabarovsk rayon power generation administrations; the Tadzhik Main Power Generation Administration; and a number of others. The reason for this is a lack of the necessary efficient monitoring on the part of the USSR Ministry of Power and Electrification

over the execution of the existing directives and decrees and an obvious shortage of the labor and technical resources that the leading organizations need to carry out the duties with which they have been charged.

3. The organs of the Gosstandart are not doing enough to bring the policies that they have developed to life. In particular, the head organizations with regard to systems for managing classification systems in the sectors of various ministries are being very slow to develop and transmit individual classes of the All-Union System of Classifying Industrial and Agricultural Production (for example, those concerned with ferrous and nonferrous metals), which makes it necessary to include a great quantity of local codes that have not been well established into the files of the All-Union System of Classifying Industrial and Agricultural Production. The Gosstandart is not monitoring and not meeting requirements related to the mandatory inclusion of the All-Union System of Classifying Industrial and Agricultural Production codes in the accompanying documents of products that it ships, which greatly complicates managing charts during the warehousing and accounting of physical assets.

Under today's conditions of restructuring and the acceleration of the country's social and economic development, special importance is being given to standardization and information compatibility during ever-increasing volumes of communications between branches. Accomplishing these tasks requires performing the work entailed in classifying and coding technical and economic information with absolute efficiency and speed.

Above all, this requires the following:

organizing (within the USSR Ministry of Power and Electrification) a methodological council with broad decision-making powers as is currently being done with regard to the subsystems of the Automated Control System for a Sector of Industry);

equipping the head and leading organizations with regard to managing the Unified System of Classification and Coding of Technical and Economic Information with the required computer technology and communications equipment; and

disseminating the organizational structure of the management system not only to electrical power generation but also to construction, the industrial construction industry, and planning and design organizations.

Footnotes

1. GOST 6.01-87. "Yedinaya sistema klassifikatsii i kodirovaniya tekhniko-eknomicheskoy informatsii. Osnovnyye polozheniya" [Unified System of Classification and Coding of Technical and Economic Information. Main Policies].

2. Yavnykh, I. S., "Organizatsiya rabot po vedeniyu obshchesoyuznykh i otras :vykh klassifikatorov tekhniko-ekonomicheskoy informatsii. Ekspress informatsiya. Sredstva is sistemy upravleniya v energetike" [Organization of Works to Manage All-Union and Sectorial Systems for Classification of Technical and Economic Information. Express Information. Control Equipment and Systems in Power Generation], Moscow, Informenergo, No 4, 1983.

'Peaceful Atom' Becomes Disputed Subject

18610485 Leningrad LENINGRADSKAYA PRAVDA in Russian 6 May 89 pp 2-3

[Discussion with Vyacheslav Mkhaylovich Sedov, corresponding member of the USSR Academy of Sciences, head of the department of radiochemical processes of nuclear energy engineering of Leningrad Technical Institute imeni Lensovet; Vladimir Aleksandrovich Kurnosov, director of the All-Union Planning and Scientific Research Institute of Complex Energy Technology, doctor of technical sciences; and Anatoliy Pavlovich Yeperin, director of Leningrad Atomic Electric Power Station, candidate of technical sciences, winner of the Lenin and State Prizes; conducted by I. Lisochkin]

[Text] These disputes and the seething of passions will apparently continue for a long time to come. The "peaceful atom," about whose existence the public knew practically nothing for many decades, turned out to be not at all peaceful and ended up as the Chernobyl tragedy—a "revelation" to millions.

An avalanche of articles and open letters filled with furious commentary rolled across the pages of the press and their were many protest gatherings and meetings. And... it subsided, without making any positive changes on the whole. It immediately revealed the incompetence of those who were "against" and the professional limitedness of who were "for." And the public, because of its inadequate "atomic literacy" ended up facing atomic energy, to put it bluntly, like a savage facing a steam engine. And the problem that bothers many people is, of course, still there.

"Why do you not write anything about the LAES [Leningrad Atomic Electric Power Station]?"—this question was heard at the meeting of workers of the editorial staff with the collective of Lenelektronmash [Leningrad Production Association for Electronic Machine Building]. This is not absolutely true. At the beginning of last summer we published a conversation with specialists who discussed how the "lessons of Chernobyl" had been taken into account and what had been done to increase security at the LAES.

But we understand that today many people are bothered not only by the technical aspects of the problem but also by many others—economic, ecological, social, moral. Therefore our special correspondent I. Lisochkin took the questions that are most frequently asked in the editorial mail and asked three specialists to answer them: Vyacheslav Mikhaylovich Sedov, corresponding member of the USSR Academy of Sciences, head of the department of radiochemical processes of nuclear energy engineering of the Leningrad Technical Institute imeni Lensovet; Vladimir Aleksandrovich Kurnosov, director of the All-Union Planning and Scientific Research Institute of Complex Energy Technology, doctor of technical sciences, and Anatoliy Pavlovich Yeperin, director of the LAES, candidate of technical sciences, winner of the Lenin and State Prizes.

Correspondent: In this discussion I think we should present the reader with the facts which he can then weigh and evaluate. And I want common sense to prevail here. Therefore I am making a commitment not to shower you with accusations and slogans to the effect that the Ministry of Power and Electrification intends to build stations over the entire country. And I shall hope that those participating in the discussion will not engage in a defense of departmental interests.

Sedov: I assume that we all agree with this suggestion. Now, unfortunately, the speeches of opponents and proponents of atomic energy remind one of the argument between two deaf people. There is no desire even to listen to the opposing side. But it seems to me that it is necessary to consider all the facts and all the arguments not only from the standpoint of common sense but also—since we are speaking about a subject that is extremely important to the people and to the country—with the highest degree of responsibility.

Correspondent: Anatoliy Pavlovich, let us return briefly to the preceding conversation. In it we discussed a number of significant technical measures for increasing the safety of the LAES. Then some of them were carried out and some remained in the plan. What progress has been made in this direction?

Yeperin: I shall quote the conclusions of the expert commission which investigated the LAES on instructions from the CPSU Central Committee: "The station's energy blocks are operating reliably at the present time. The immediate and combined measures taken at the LAES have provided for a reduction of the steam generation response coefficient and an increase of the speed of the SUZ [monitoring and protection system] to the earmarked level, which provides for the prevention of a rapid, uncontrolled reactor surge and strong energy bursts in all emergencies..." You know that 80 control rods have been added to each reactor and the protection control systems have been modernized... Today we are continuing to work not on the hypothetical elimination of accidents but on the prevention of the very possibility of the appearance of an accident situation. The subtext of your question is probably this: "Perhaps they made a little noise and then forgot about it?..." No. Everything that was earmarked has been done or is being done within the established time periods.

Correspondent: After 26 April 1986 even discussions of increased reliability and safety of atomic energy stations are heard without enthusiasm. And many people (and I am not exaggerating) have simple questions: Did we not make a mistake by developing atomic energy? Is it really necessary at all?

Sedov: There are no alternatives to atomic energy. Actually, all disputes should revolve around this axiom. But for some reason this does not happen. In their arguments people forget the main thing: in our age mankind has no other path to obtaining the energy we need than the development of atomic energy. The traditional sources of energy (coal, petroleum) are being depleted and it is becoming economically disadvantageous to extract them. The old coal mining regions are experiencing great difficulties. You have probably heard about the "Donbass problem." In the new mines we must mine coal with a high ash content and a high percentage of sulfur. As concerns petroleum, according to the calculations of the leading economists, after 2010 it will simply be impossible to increase its extraction.

Of course one can criticize the policy of the Ministry of Atomic Power as much as one likes. But let us ask ourselves a question: What about the other countries of the world; are their atomic energy ministries "villains" as well? This is absurd. Atomic energy originated as a natural phenomenon of technical progress. Its utilization began at practically the same time in all developed countries. And we should recall with gratitude our great predecessors, the physicists and atomic energy engineers whose work and talent have made it possible for our country not to be hanging on to the shirttails of technical progress.

Correspondent: This opinion is fairly widespread: nuclear energy engineering was born "prematurely." People speak and write about the notion that in 10 or 20 years completely safe stations will be created and that it is better to use coal and gas until this time comes. After all, cases like this are known in the history of technology. Each of us understands that our posterity will be moving through the air at supersonic speeds, but the TU-144 created in our day has "not flown"...

Kurnosov: The "flight" of atomic energy began not yesterday and not the day before, but 40 years ago, with the first Siberian atomic power stations. An immense amount of experience in a branch that is operating stably has been accumulated over these years.

As concerns "absolute safety," this will never be. There is not a single complicated technical device, whether it be a space ship, a sea liner, or simply an automobile, no matter how you develop "fool proofing" (to use a well-known American expression) that will every be completely safe.

Of course an atomic boiler is no joke. It requires the appropriate technical sophistication. Chernobyl was possible not because the RBMK-1000 reactor was "bad" or because the technical regulations in effect at that time were "bad." The main factors that led to the steam explosion and the destruction of the reactor were irresponsibility, negligence, and a lack of technical sophistication.

They conducted an experiment there which, excuse me, is not worth a brass farthing when the emergency panel is lit; they violated everything that could be violated, and they actually achieved the improbable by "exhausting" the reactor. I believe that many people have read the conclusion of the government commission and the materials from the trial of the people to blame for the accident. Everything is evaluated correctly in them.

Correspondent: Vyacheslav Mikhaylovich, you mentioned the impossibility of an alternative path. It has been calculated that the potential possibilities of wind energy in our country are equal to more than 10 billion kilowatts. A colossal figure! It has also been suggested that we step up work on solar installations and "small" GES's [hydroelectric power stations]. And many people are convinced that this will make it possible to refrain from AES's [atomic electric power stations] completely.

Sedov: It is easy to calculate the amount of energy in the wind. The problem lies elsewhere; there is no way to get ahold of it. There are no installations which could effectively transform it into electric energy. Neither in our country nor throughout the rest of the world. In exactly the same way we know that there is colossal energy in the ocean and sea waves. But again there is no hope of a technical solution.

But I think that these "alternative" sources deserve attention. The Americans have gotten furthest in experiments on using the energy of the wind, and our "wind engineers" are lagging behind them. I am sorry to say this because the application of various kinds of "windmills," solar installations, and "micro-GES's" could be extremely useful for enterprises and population points that are distant from the country's unified energy network as well as for various kinds of expeditions.

But with all this to assert that these energy sources can replace TETs's [thermal electric power stations], AES's, and GES's, means simply to deceive the public. They are all a bluff.

Yeperin: The LAES produces 60 percent of the electric energy in our region or 2 percent of that in the entire country. What kind of "windmills" would you order to replace it?

Kursonov: I hold the same viewpoint. And all the discussions about "alternative" sources remind me of the story of "small-scale metallurgy" in China during the time of the "Great Leap Forward." Do you recall the outcome of this immense economic Panama rooted in politics? We must not repeat mistakes like this. And any basically literate economist can figure out what is going on here.

Correspondent: If it is all so simple then why are there so many different attitudes toward atomic energy in different countries? Some are developing it (France, the United States) and some are curtailing it (Sweden, Denmark)? Who is right?

Kursonov: It is simply a matter of the country's economic policy and how advantageous it is to produce electric energy. It is understandable, for instance, that countries with large supplies of natural fuel have less need for AES's. Others—Japan, for example—have had to force the development of the atomic energy program even under extremely difficult seismological conditions. For still others, with a particular set of economic market conditions, it is more advantageous to purchase energy from their neighbors than it is to produce it themselves. There can be various variants here. But the main thing is still the same: the overall quantity of energy produced in the world has grown and continues to grow. This is a law of development of the human society which nobody can repeal.

Correspondent: Permit me to object. We know of examples in which entire countries achieve an increase in industrial output with a simultaneous reduction of energy consumption. If one is to believe the literature, the United States managed to reduce the energy-intensiveness of production by 33 percent, and Japan by 78 percent. And the question is legitimate: "What about us? Are we unable?... Or do we not want to?"

Sedov: There is no energy engineer who would not welcome measures directed toward economizing on electric energy and introducing energy-saving technologies. Yes, we frequently waste it disgracefully. Just think of the lamps that burn 24 hours a day on stair landings. Year after year measures are planned for economizing on electric energy. But, as we know, everything remains the same.

All of us are proponents of energy-saving technologies. There can be no contradictions or various viewpoints here. But let us imagine this picture. Starting tomorrow we reduce the output of electric energy by 78 percent and say, "Let us work like the Japanese." What will happen? Everything will come to a halt. Why? Because before applying energy-saving technologies it is necessary to create them. It is necessary to retool practically all kinds of industry with different machines and mechanisms. Are you sure that this is a realistic task for tomorrow? Here we must stand firmly on the ground we have under our feet.

Kursonov: Let me add that in this dispute we should not substitute concepts. There are "energy-intensive" and "electricity-intensive" products. These are by no means the same thing. A reduction of energy-intensiveness

cannot serve as reason for refraining from the development of electric power stations. Because in developed countries which have achieved a significant savings on energy resources the energy-intensiveness of the products is decreasing and the electricity-intensiveness is increasing. It is not difficult to understand why this is happening.

Correspondent: But still there is a "threshold" in the perception of atomic energy engineering. Public opinion is fairly simple: regardless of the advantages it may promise, we must not be "atomic hostages," we must not try to justify possible victims—this is immoral.

Sedov: Let us talk about morality. We all know about Chernobyl and not from any magazine or newspaper accounts. We have worked on eliminating the consequences of the disaster. Vladimir Aleksandrovich, for example, was instructed to design and construct a "sarcophagus" which has never before existed in the history of technology, and this work was done in five and a half months... I think that as eye witnesses and participants in the Chernobyl events we have the right to express our opinions.

Yes, 30 people died in that extremely terrible disaster in Chernobyl. Among them, our colleagues, there were both heroes and martyrs. These deaths cannot be justified. But look at what the proponents of "traditional kinds of energy" are saying. Fuel for them means a peaceful little fire in the fireplace. And yet in the world mining industry and average of 2,500 people die terrible deaths each year in serious accidents. So can the death of 2,500 people each year be justified, can it be considered "normal"?!

I shall mention one more attempt to deceive the public. Sometimes AES's are called "radiation polluters of the environment." But they say nothing about the fact that in reality they are among the ecologically cleanest sources of energy. The people who are so enthusiastic about coal, the very ones who recommend "holding on" to it a little longer, do not say anything about the fact that burning coal produces uranium and radon radiation. For each unit of capacity an ordinary thermal electric power station produces 40 times more radioactive discharges than an AES does. Moreover, its discharges contain many other substances that are harmful to man's health, including carcinogenic ones. It has been calculated that the operation of a thermal electric power station is approximately 100 times more dangerous than an atomic station. Everybody should probably know these things as well.

Kursonov: I shall continue what was being discussed by Vyacheslav Mikhaylovich. Now thermal, hydraulic, and atomic energy stations comprise a unified energy complex. Of course we are not speaking about replacing one with another. But we must absolutely objectively evaluate the merits and shortcomings of each type of station and realistically see its advantage and harm.

Everyone has undoubtedly heard about the "acid rain" that is destroying the main forests of Europe. They are the result of the burning of solid fuel. And these rains are no conjecture, but, alas, an already long-standing reality.

But even they are not the main thing or the most dangerous thing for nature. Now throughout the world people are unanimously sounding the alarm about the "greenhouse effect" which is developing because of the combustion of organic fuel on an ever increasing scale. If this phenomenon is not halted, mankind will see an unprecedented ecological catastrophe. Who is searching for a solution today and where? Britain has announced a new program for building atomic electric power stations instead of thermal ones, and here it is emphasized that its implementation is the country's contribution to the fight against the "greenhouse effect." This is how certain things are in the world arena.

Correspondent: Let us try to shift from affairs on a world scale to our own local ones. Before Chernobyl Leningraders were quite satisfied with reports about the "atomic energy river" while now I think that everyone is keenly aware of the presence of the LAES only a couple dozen kilometers away from the city. Tell us, Anatoliy Pavlovich, what is the current radiation situation in Sosnovyy Bor?

Yeperin: The same as in Leningrad. True, not everyone believes this. There are artistic collectives who consider the demonstrations in Sosnovyy Bor to be their own personal feat and there are those who are afraid to go there at all. But to walk through our city is in no way more dangerous than to walk along Nevskiy Prospekt. Perhaps it is even better: we have neither soot nor ashes... And this has been the situation in Sosnovyy Bor during all the 15 years the LAES has been in operation.

Correspondent: But yet the LAES is not isolated from the environment but interacts with it. Any new person who comes to Sosnovyy Bor is struck by the tall smokestack of the AES which, one must assume, was not built without reason, and the river which flows from the station 24 hours a day. True, I had occasion to read in one of the old reports about the LAES that the station "discharges water with radioactivity of less than that in the natural background." I am no physicist but this even amused me a little... So what kind of water are you discharging into the Finnish Gulf?

Yeperin: Indeed, the station can discharge water with a level below that of the natural background only in theory. This does not happen in reality... Each hour we take from the Finnish Gulf a million cubic meters of water which is use to cool the reactor's systems and we return an equal amount. The only difference is in temperature. The water that is discharged is 6-10 degrees warmer. It would be very tempting to salvage this heat, but, unfortunately, science and technology have not yet found a way of doing this.

Correspondent: They say that the immense amount of heat discharged by the LAES raises the temperature of the gulf by 1 degree, which can lead to unpredictable ecological changes, interrupt the traditional migratory routes of fish, and stimulate the growth of blue-green algae.

Yeperin: This is from the realm of conjecture and presupposition. In reality this heat is fully "dissolved" in the annual and fairly significant natural fluctuations of the gulf's temperature. Moreover, the circulation of the water is essentially limited to the Kopor Bay and in general can exert no influence on the Finnish Gulf.

The LAES actually does cause a certain amount of harm to fishing. Our pumps, like any other power pumping installations, take in along with the water young fish entering the intake channel. In order to compensate for this damage, a fish hatchery is being constructed as was envisioned by the plan.

Correspondent: There are persistent rumors that the first reactor is in a dilapidated condition and that a "sarcophagus" is required for its early burial.

Yeperin: Absolute nonsense! We were all in the reactor and machine bays and also at the control panel for the first block. You saw that after the planned repair it will reach its full capacity. In 4 years every reactor undergoes capital and intermediate repair and 6 scheduled maintenance operations. Such is the mandatory cycle.

And the rumors are a complete distortion of what we actually have to do. With time, as a result of many years of work in the reactor there is a certain reduction of the initial clearance between the technological channels and the masonry. This problem is well known and was envisioned in the basic plan. Therefore this year we are beginning regular replacement of the technological channels with calibration of the graphite cells. This is a normal, as we say, "scheduled" operation. And its implementation will make it possible to prolong the period of operation of the station up to 40-45 years.

Training Facility for Nuclear Power Plant Operators Opens in Energodar

18610440b Kiev PRAVDA UKRAINY in Russian 9 Feb 89 p 2

[Report by A. Golovin, RATAU correspondent]

[Text] Energodar, Zaporozhye Oblast, 8 Feb. A branch of the All-Union Advanced Training Institute for Managerial Personnel of the USSR Ministry of Power and Electrification has opened here.

The creation of such a learning center was dictated by life itself, according to the Acting Deputy Director of the Branch A.V. Barzenkov. Today, the nuclear power industry is called upon to carry out the State's order to raise the professional competence level of management and experts who could be entrusted with supervising the construction and operation of nuclear power plants (AES).

The instruction will be conducted by a skilled faculty, including experts from the USSR State Construction Committee and Power and Electrification Ministry, as well as enterprises, organizations, and scientific research and design institutes of the industry.

UDC 658.52.011.56

Synthesis Problems of Flexible Production Systems

18610427a Kiev MEKHANIZATSIYA I AVTOMATIZATSIYA UPRAVLENIYA; NAUCHNO-PROIZVODSTVENNYY SBORNIK in Russian No 3, Jul-Sep 88 pp 1-5

[Article by N. P. Starodub, candidate technical sciences]

[Text] The actual way to increase the efficiency of machine building and instrument building enterprises is to create a flexible integrated automatic production system (GIASP). The use of GIASP reduces considerably warehouse stocks, sizes of storage spaces and financial costs and, moreover, saves power and raw materials, reduces waste and scrap. It also reduces direct and indirect labor, as well as reducing time for assembling new products. It will increase the rate of production and the percentage of high quality product output.

In the general form the GIASP model (Fig. 1) can be shown as a totality of preparation systems (ASNI, SAPR, ASTPP and personnel) supply (ASODU, ATSS, ASIO, ASUO and ASK) and a flexible production system (GPS).

GPS plays the main role in solving the problems of automating series and small-scale production. The synthesis process of a specific GPS must be based on analyzing its basic functions. In this connection, the most promising direction in intensifying production on an automatic basis is to change over from using individual NC machine tools to creating and introducing flexible production modules and flexible automated sections and then—flexible automated shops.

Such a changeover has become possible by creating modern NC systems type CNC, SNC, DNC as well as NEWRON IZ.611, NEWRON IZ.616, NEWRON IZ.617, 2R32, 2642, 2S85 etc., which span the basic pool of metal-cutting equipment—lathes, milling machines, machining centers and GPM. These systems are more reliable and more adaptable for repairing and it is possible to build them into metal-cutting equipment. They can be used to test the machining process, monitor parts actively and monitor automatically the wear and integrity of the tool with a correction in the control program by the use of an upper level computer.

The model of a flexible production system S can be represented in the form of a composition of two models:

$$S = M \,.\, P, (1)$$

where M is the model of a GPS control structure; P is a model of the GPS equipment structure.

The model of the control M structure makes it possible to synthesize efficient GPS and determines the relationship between the architectural input of computers, taking into account time and power limitations, as well as the time between apparatus and program facilities depending upon the algorithm for processing input data flows, and the given accuracy and reliability of the complexes being developed. Model M is a procession of six components.

$$M = \langle X, Y, A\,(X, Y), B, C, D\rangle, (2)$$

where X is the number of analyzed input signals; Y is the number of S algorithms; B is the number of the given algorithms of intrasystem apparatus-program realization; D is the number of characteristics of the data transformation process.

Numbers C and D set a single-valued correspondence between the realized algorithm and its reflection on the GPS structure.

Model P of the GPS equipment structure has the form

$$P = \langle N, T, Q\,(C, F, I, K)\rangle, (3)$$

where N is the means for storing products; T is the means of distributing and transporting; Q (C, F, I, K) is the number of technological procedures realized by machine tools C, fixtures F, tools I and monitoring means K under the control of built-in microprocessors (Q).

In creating the M model, it is necessary to bring into correspondence structural transformations of data in the X set, semantic and statistical transformations in the B set and structural transformation in the Y set.

The basic problems of synthesizing the GPS are the development of methods to design apparatus and the software, and the realization of the data, program, apparatus and organizational integration of all subsystems.

Organizational integration is provided by the comprehensive implementation of the following functions: operational-calendar planning, operational monitoring, accounting and analysis of production progress and of equipment control.

The problems of operational-calendar planning consist of the formation of schedules for starting-up the production of intermediate products and readjustments of equipment; the determination of the quantity of intermediate products and tools necessary to implement the tasks in a certain time interval, etc.

The operational monitoring, accounting and analysis of the progress of production must span the output of products, incomplete production, idle time of equipment, utilization of tools and accessories.

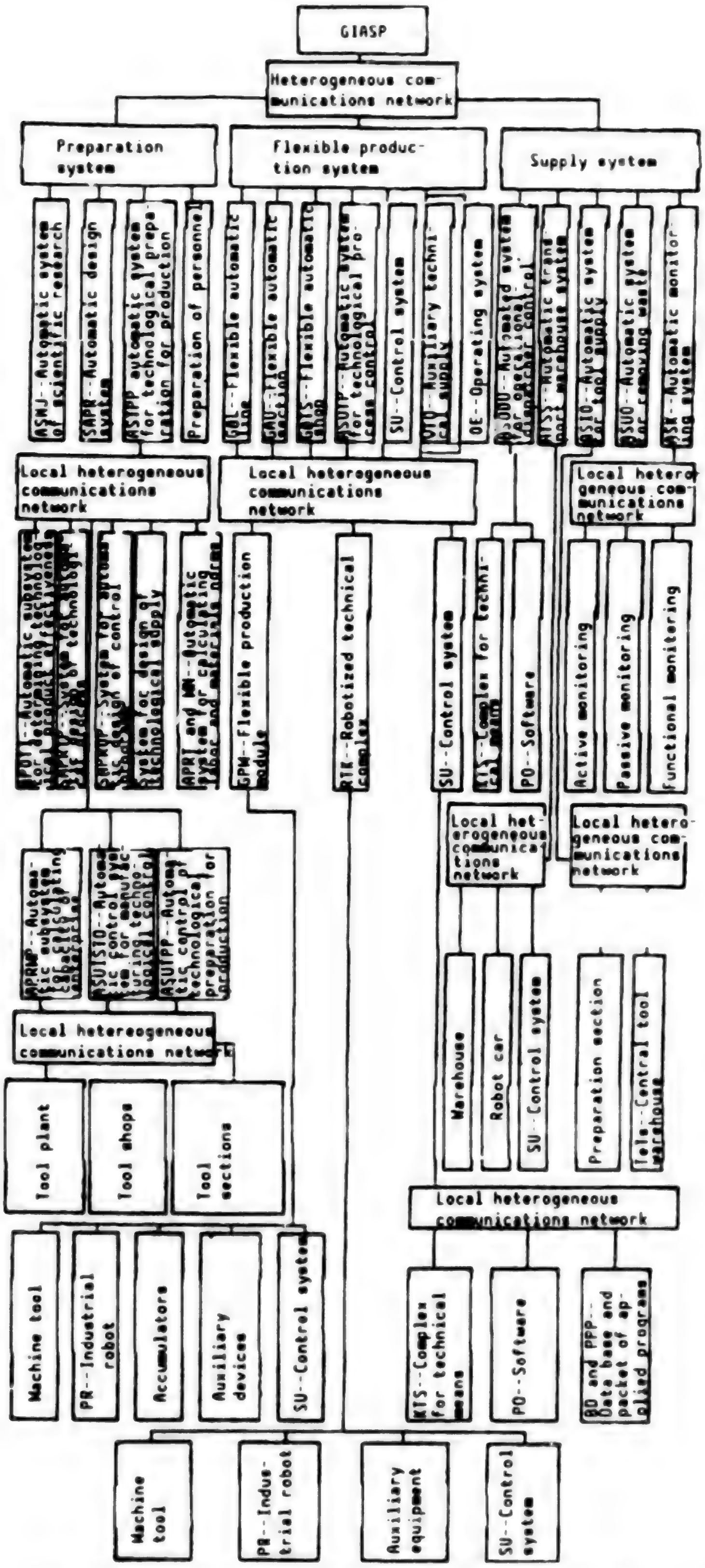

Figure 1. Model of Flexible Integrated Automatic Production (GIAP)

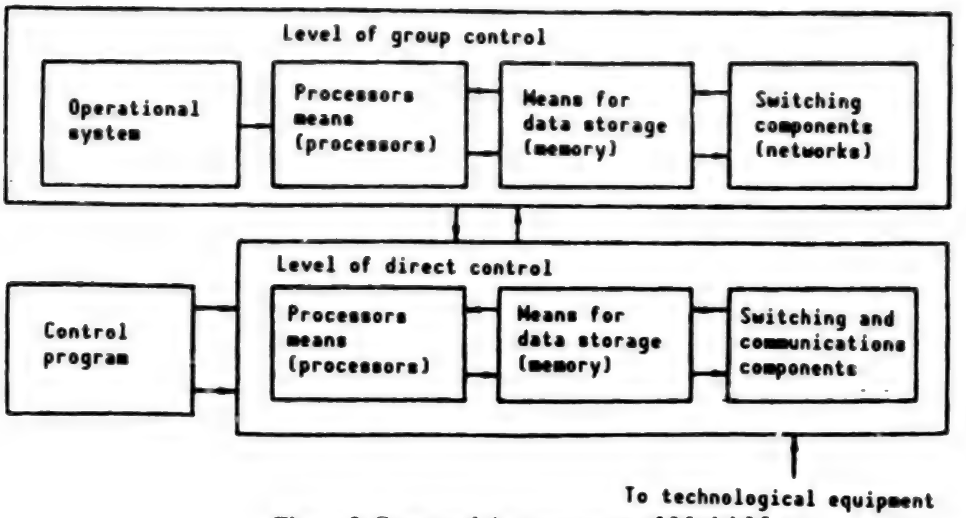

Figure 2. Structural Arrangements of Model M

Input data for all problems is data introduced from the upper control level and received from the local lower control systems. This data is stored in the data base, the organization and the direction of which are provided by means of special programming.

Apparatus and program integration is implemented by combining all technical means into a single heterogeneous network which, at the lowest level (work position) consists of programmed controllers, NC systems (NEWRON IZ 611, NEWRON IZ. 616, NEWRON IZ. 617 etc.); at the section level—of SM-1420 type mini-computers or NEWRON I9.66 personal computers; at the upper level—powerful YeS series computers.

Four types of functional elements can be separate in the GPS control structure (Fig. 2): processors; memory (data storing); switching and exchange elements; means for controlling processes and resources (operational systems and local controllers). It should be noted that the separated functional elements are common to all levels of hierarchic GPS control structures.

Data exchange between various control levels are implemented by local and heterogeneous networks[1]. The use of network architectures in the GPS provides for data compatibility—a necessary condition for the efficiency of the system.

The use of the principles of program control predetermines the flexibility of the system when changing over for the output of new products or changing planned tasks.

In the structure of equipment P is is also possible to separate four types of elements, functionally similar to the structural elements of control: (Fig. 3) technological equipment; intermediate storage units, warehouses for intermediate products, tools, and finished products; means for distributing and transporting; local (built-in) control subsystems, for example, an NC system for lathe and milling equipment.

The functional generality of control M structures and of equipment P structures makes it possible to utilize common criteria in evaluating the efficiency of various versions of the specific technical implementation of the indicated subsystem.

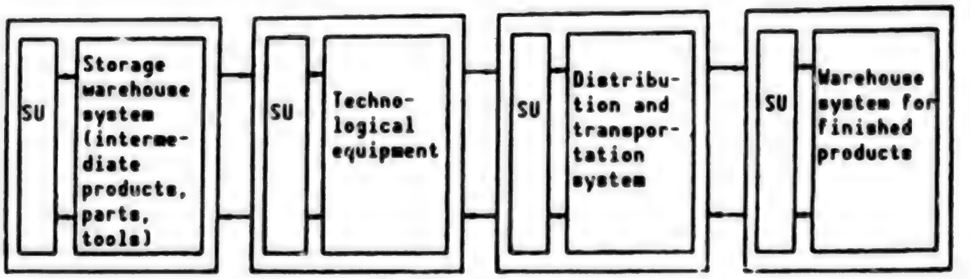

Figure 3. Structural Arrangement of Model P

Group criteria of the M and P subsystems can be expressed in the form

$$K_i(M) = \sum_{j=1}^{n} g_j K_{ij};$$

$$Z_i(P) = \sum_{j=1}^{n} P_j Z_{ij},$$

where g_j, P_j are weight coefficient indicators correspondingly of K_j and Z_{ij}.

Technical-economic characteristics of functional elements of the M and P subsystems can be used as indicators K_{ij} and Z_{ij}.

Thus, the productivity of the central processor computer CM-1420 may be taken as parameter $K_{ij}=K_{11}$, while the productivity of the technological equipment (lathes or milling machines, chemical-galvanizing lines etc.) may be taken as parameter $Z_{ij}=Z_{11}$.

Parametric K_{12} can designate the capacity of the operational memory of the control system computer while Z_{12}—the capacity of the intermediate storages of GAU, GATs etc.

In the structure of the integrated SAPR of the enterprise it is possible to separate three levels: first (upper) level which solves problems of organizing communications between SAPR and ASU, including problems of planning, material-technical supply and operational-dispatcher control at the enterprise level; the second is a level of technical and programming means for the direct solution of design and construction; the third is the microprocessor controllers level for direct control of technological equipment.

The second level facilities are implemented in kthe form of the local automated work positions (ARM) of designers. ARM with personal computers are the most promising.

The availability of color display in personal computers for input-output of symbolic and graphic data, multicolor plotters, graphic data coders, as well as network controllers makes it possible to create a wide list of ARM of various profiles. The operation of personal computers in the modes of an emulator of a YeS computer terminal provides the necessary communications between the upper and middle SAPR levels, as well as access of personal computer users to lthe data files of the YeS computer of the upper level.

The functional elements of the GPS (processors, memories, switching and exchange elements, operational systems and application software) make it possible to solve, also, besides technical equipment control problems in the process of production problems of product design and the technological routing for their production. The GIASP and GPS models described have been developed and are being introduced at the Kiev Production Association imeni S.P. Korolev.

Footnotes

1. Sleptsov, A.M. and Yurasov, A.A. Automation of designing control systems for flexible automatic production. Kiev, 1986.

UDC 725.42: 658.011.56

Local Networks of Robot Technological Complexes and Personal Computers for the Production of Electronic Equipment

18610427b Kiev MEKHANIZATSIYA I AVTOMATIZATSIYA UPRAVLENIYA: NAUCHNO PROIZVODSTVENNYY SBORNIK in Russian No 3, Jul-Sep 88 pp 42-43 pp

[Article by Yu. V. Abramov and M. V. Nikolayev]

[Text] To achieve the greatest efficiency, the modern robotized production of electronic equipment (IET) must span the entire cycle of production: from individual assembly-repair and technological operations to storing and preparing documentation for each lot of products. Assembly-repair and technological operation are done by robot-technological complexes (RTK) that manipulate (accumulate and deliver to technological positions) IET components and control the technological process (for example, contact welding: seam, point, soldering etc.).

Personal computers (PC) coordinate RTK operation and process statistics, as well as formulate documents and controll the warehouse. In order to combine RTK and PC into a single whole to achieve coordination of IET production control, it is proposed to use a number of systems including a microprocessor system for positioning, and cyclical RTK control; a special local network (SLS) RTK and PC whose program structure is a distributed operational medium for organizing an optimal parallel implementation of technological operations to achieve maximal productivity of IET production; a system for developing and checking out applied software and its efficient changing when production technology changes.

The architecture of the local PC and RTK network is determined by the following properties of IET robotized production: by parallel actions and distribution of RTK and PC in the shop; asynchronous and quick action; inhomogeneity; indeterminacy due to unforeseeable behavior of the RTK and operators when using PC at each moment of time, by unsteadiness; by flexibility.

According to the principles of the functional architecture of the local network and the decentralized and asynchronous principles of control, computer facilities are placed as close as possible to where data originates and is applied.

The logical structure of the local RTK and PC network is a totality of asynchronous processes, connected to RTK and PC resources whose parallel development and data interaction determine a given technological cycle.

The RTK computer system[1] is a mainline-modular system of positional and cyclic control implemented by a selection of functional-design modules (FKM), combined by a distribution frame of an intermodular parallel interface (GOST 26.765.51-86) which makes possible modular selection according to the common principles of a wide number of control systems. The FKM control is implemented by a single-plate microprocessor built of a set of K-1801 microprocessors. SLS units are PC, DVK-1, DVK-2 and DVK-3.

The SLS program structure is a distributed operational medium for maintaining the development and interaction of asynchronous processes in RTK and PC which was developed, taking into account functional requirements due to the presence in IET robotized production facilities of highly developed programs for process interactions. These programs are efficient and convenient for handling interruptions, providing uniform access to the operational medium and symmetrical interaction of processes in one and various units; providing remote loading; using the real time mode with a minimum amount of memory; the network software is reliable and has the means of dialog in each unit. The SLS has a "star" type of topology at whose center is the "Elektronika-85" PC. The central operational PC system is an OS [Operating System] RV [Real Time] SM computer. The network superstructure above the OS RV includes two of the most important problems and an internal message driver. In the remaining network units the operation medium is a specialized operating system which maintains the high level mechanism of process interaction and the multiprogram and real time modes. The specialized operation system occupies a volume of 14K levels and can be placed in the permanent memory.

Each process in the system is identified. Message exchange between any processes is implemented by special interaction operators who call for special functions of the medium. The basic instructions are sectional, based on the concept of the "interaction cycle".[2]

When a message is sent, a sectional instruction of the "send message-receive answer" is implemented. This instruction consists of three parts: send message to a certain process, implement (not compulsory) some operations and the receive a response message. When a message is received, the sectional instruction of the "receive-answer" type or "receive-or transmit further" is implemented. Besides using interaction operators, messages can also be exchanged by two methods: interaction without blocking and interaction by signals. Some 13 process interactions are implemented in the operational distribution medium. The operational distribution media has a number of advantages over various systems used in automated production facilities: they span all SLS units and software not only of transport services, but also of the necessary system functions in each unit; they are simple and efficient to use and make it possible to impose network functions on the unit itself without changing its basic function, and eliminates a network controller; it is possible to store the software of the network unit in the permanent memory.

The system of developing and checking out the applied software (PPO) of SLS functions on the basis of the PC. The PPO are developed in "Elektronika-85" PC in a medium of OS RV in MAKRO—and SI languages as a totality of asynchronous processes. The expansion of the possibilities of the SI language make it possible to develop PPO in terms of asynchronous parallel processes in implementing RTK functions. After composition, the PPO is transmitted over communication lines to RTK and PC for comprehensive check-out, after which it is stored in the permanent memory (for the RTK) or stored in the central PC while before the start of operation, it is stored in the SLS unit (for the PC).

The use of a local specialized network for the RTK and PC in the NIIAT and in the NIITOP made it possible to use new approaches in creating robotized production facilities and achieve great efficiency.

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UDC 621.33:518.5

Program Complex To Automate Study and Modeling of Manipulation Robots

18610361a Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan-Feb 89 pp 104-107

[Article by S. V. Yeliseyev, M. M. Svinin, S. A. Baranov, and A. V. Gornakov under rubric "Flexible Manufacturing Systems and Robotic Production-Process Systems": "Program Complex To Automate Study and Modeling of Manipulation Robots"]

[Text] The process of researching, modeling, and designing industrial robots requires solving a rather extensive number of problems of the kinematics, dynamics, and

statics of manipulation systems of industrial robots as well as problems related to planning and controlling their motions.

This article examines a program complex to automate the study and modeling of manipulation systems representing multilink three-dimensional mechanisms with open kinematic chains.[1-3]

Description of the actuator. The following assumptions have been made in the mathematical description of the industrial robot's actuator:

—the actuators consist of absolutely rigid link/bodies that are connected by class 5 kinematic pairs and that form an open nonbranched, kinematic chain;

—higher-class kinematic pairs are modeled by introducing fictitious zero-length links;

—one of the terminal links (the stationary base member) is considered conditionally immobile;

—the elastic links are modeled by breaking a real elastic link into a series of absolutely rigid links connected by kinematic pairs in which elastic forces are operational.

When the coordinate system is introduced, each link in the kinematic chain is associated with its own system, the numeration of which coincides with the number of the link. The base triad of axes $X_0Y_0Z_0$ is associated with the stationary base member.

The kinematic model is designed on the basis of recurrent relationships connecting the coordinates, velocities, and accelerations in the i-th coordinate system with their respective values in the (i - 1)-th coordinate system.[2] The inverse kinematic capabilities are solved by using minimization methods.[3]

The dynamic model of the actuator is formulated in the form of an Epple or type 2 Lagrange equation. The equations are solved relative to generalized coordinates:

$$A(q)\ddot{q} + B(q, \dot{q}) = Q(q, \dot{q}, t) + P(q, t).$$

The geometric model of the industrial robot's actuator is constructed by using polygonal networks that make it possible for formulate a base of geometric primitives. By using set-theoretical and logical operations on the geometric primitives, the user describes the geometry of the industrial robot and its environment.

Organization of the program complex. The functional portion of the program complex is a hierarchically organized set of program modules that design the actuator and model the drive, system, control, and environment.

The first level of the hierarchy forms the base modules for calculating the kinematics and dynamics on the basis of the following theoretical mechanics methods:

—solution of primal and inverse kinematics problems;

—calculation of generalized forces from the external load;

—solution of statics problems and first and second dynamics problems;

—calculation of the frequency spectrum, amplitudes, and initial free vibrations;

—calculation of elastic deviations, velocities, and accelerations.

The second level forms modules for calculating the quality estimates of the industrial robot's functioning and motion as well as modules for estimating its inherent properties: factoring the working space based on the service, precision, stiffness, mobility, and acceleration characteristic coefficients.

The third level consists of modules that give the user access to the lower-level modules encompassing one class of problem:

—primal kinematics problems about positions, velocities, and accelerations;

—the plotting of motion programs;

—inverse kinematics problems;

—calculation of quality estimates (service coefficient, size of work area, etc.);

—investigation of coefficients of dynamics equations;

—statics problems;

—primal and inverse dynamics problems;

—calculation of forced vibrations;

—calculation of free vibrations;

—determination of intersections with obstacles.

The systems portion of the complex assumes the function of a man-machine interface, i.e., it provides convenient access to the functional portion. The functions of the systems portion are as follows: input, correction, and storage of industrial robot models; verification of the semantic correctness of the model's input; input, correction, and storage of research jobs; verification of the model's conformity to the job prior to calculation; introduction of a different type of reference service; organization of the process of calculating the job; and graphic interpretation of the calculation results.

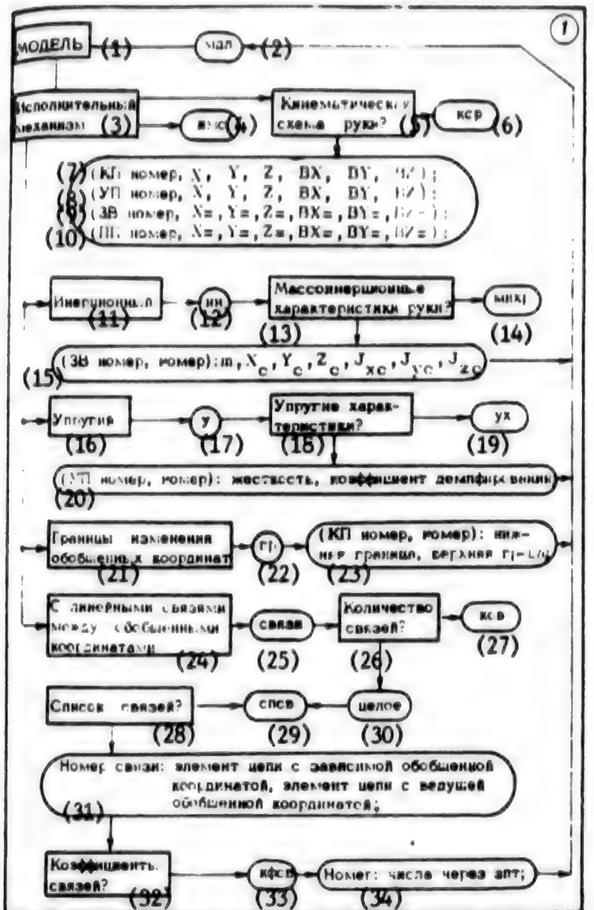

Figure 1. Logical Diagram of the Interaction Entailed in Constructing a Model of a Robot's Manipulation System

Key: 1. Model 2. Mod 3. Actuator 4. ACT 5. Mechanical diagram of arm? 6. MDA 7. Kinematic pair number 8. Elastic pair number 9. Link number 10. Movable pair 11. Inertia 12. IN 13. Inertial mass characteristics of arm? 14. IMCA 15. Link number, number 16. Elastic 17. E 18. Elastic characteristics? 19. EC 20. Elastic pair number, number 21. Limits of change in generalized coordinates 22. LIM 23. (Kinematic pair number, number): lower bound, upper bound 24. With linear connections between generalized coordinates 25. Connections 26. Number of connections? 27. NUM 28. List of connections? 29. LICON 30. All 31. Number of connection: element of chain with dependent generalized coordinate, element of chain with leading generalized coordinate 32. Coefficients of connections? 33. CFCON 34. Number, decimal number

The systems portion includes the following components: a problem-oriented language for inputting and correcting models and jobs (Figure 1 is a logical diagram of the interaction when the model is input); a file of models, jobs, and research results; a reference service of the running status of the complex and its capabilities; a job processor (its functions include generating a head job

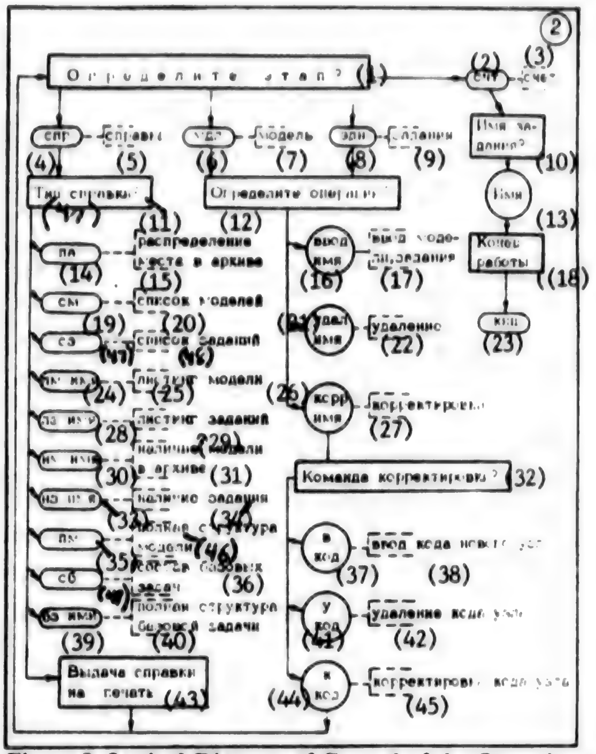

Figure 2. Logical Diagram of Control of the Operation of the PAMIR Program Complex

Key: 1. Specify stage? 2. CALC 3. Calculation 4. INQ 5. Inquiry 6. MOD 7. Model 8. JOB 9. Job 10. Job Name? 11. Type of inquiry? 12. Specify operation? 13. Name 14. DS 15. Distribution of file space 16. Input name 17. Input model and job 18. End of operation 19. LM 20. List of models 21. DEL NAME 22. Delete 23. END 24. LGM 25. Listing of models 26. CORR NAME 27. Correction 28. LGNAME 29. Listing of jobs 30. PMNAME 31. Presence of model in file 32. Correction instruction 33. PJNAME 34. Presence of job 35. FM 36. Structure of basic tasks 37. ICODE 38. Input code of new node 39. BSNAME 40. Full structure of basic task 41. DCODE 42. Delete node code 43. Print out inquiry 44. CCODE 45. Correction of node code 46. Full structure of model 47. LJ 48. List of jobs 49. SB

program and then translating, editing, and executing it); and a monitor program.

Figure 2 is a logical diagram of the interaction with a list of all possible states.

Technical characteristics. The program complex is implemented in full measure on YeS computers model YeS1022 or above with at least 300K RAM. A type YeS7927 or YeS7906 alphanumeric display (or any other display that emulates the operating mode of a YeS7927) is required to organize online interaction.-

The systems portion is written in the algorithm languages PL/1 and Assembler and occupies about 150K RAM. The functional portion is implemented in standard FORTRAN-IV and may be used in a stand-alone mode on a YeS, BESM-6, or SM computer with at least 128K RAM.

Areas in which the complex may be used. The program complex has already been tested and is being used in sectorial and academic scientific research institutes and higher educational institutions. Experience has shown that the complex is most feasibly used in the following cases:

—studying already existing industrial robots to obtain a complete idea of their properties and capabilities and to assess the possibility of including them as components of robotic production-process complexes in production processes that are already in existence or in those that are being designed;

—designing nodes of new industrial robots and robotic production-process complexes (within the framework of CAD);

—modeling industrial robots to develop and check new methods of controlling them and planning the trajectories of industrial robots' links (within the framework of an automated scientific research system);

—training students at higher educational institutions in the robotics and machine building specialties.

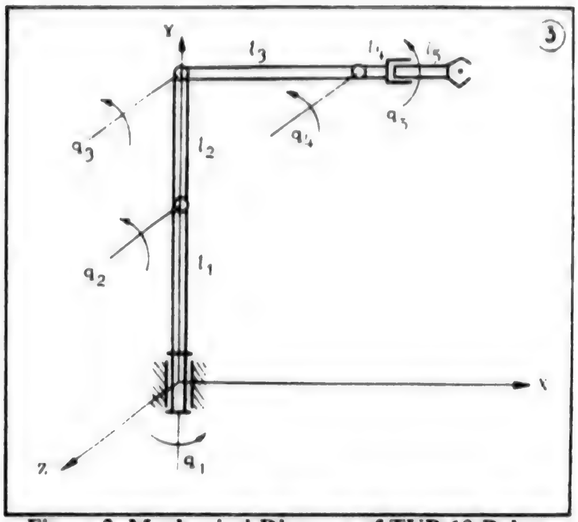

Figure 3. Mechanical Diagram of TUR-10 Robot

An example of the calculation of the movement of a TUR-10 industrial robot in generalized coordinates based on an existing grip motion in a cartesian coordinate system is presented below in order to illustrate the operation of the complex. Figure 3 is a mechanical diagram of the TUR-10 industrial robot.

Example. A description of the model (types of kinematic pairs, link lengths, and constraints on the turning angles) of the TUR-10 industrial robot has the following appearance in the language of the program complex:

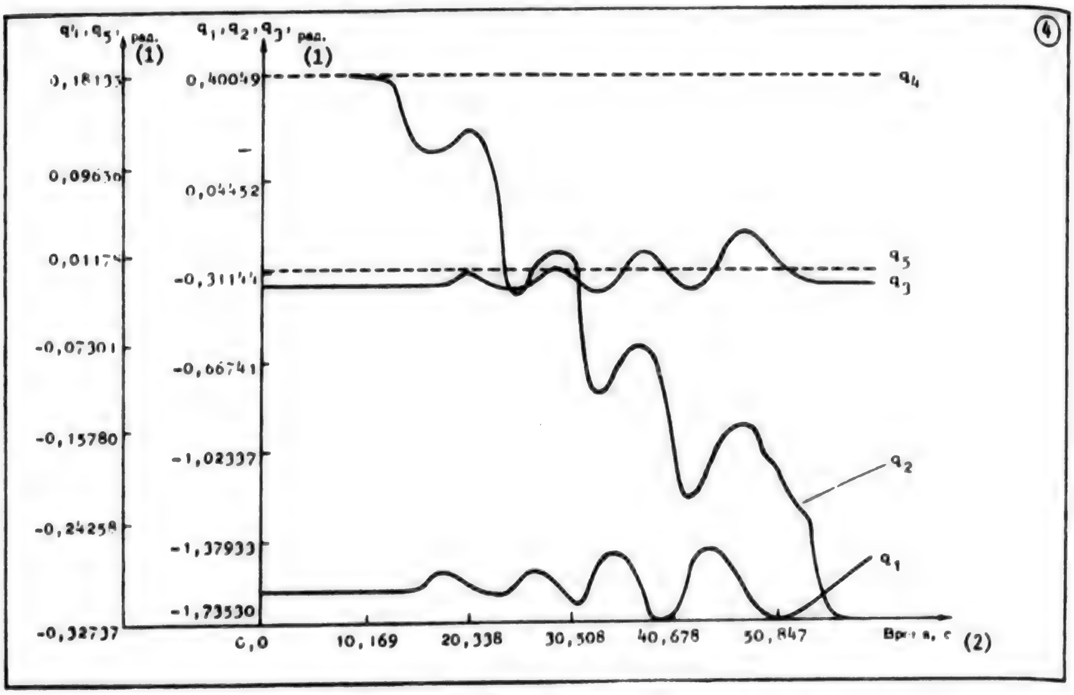

Figure 4. Generalized Coordinates of Principal Motion
(Graph Line Numbers Correspond to the Numbers of the Generalized Coordinates)

Key: 1. Radians 2. Time, s

MDA: (KP 1, BY), (LI 1, Y=0.7), (KP 2, BZ), (LI 2, Y = 0.5), (KP 3, BZ), (LI 3, X = 0.67), (KP 4, BZ), (LI 4, X = 0.095), (KP 5, BX), (LI 5, X = 0.1).

CON: (KP 1.1): -3.1, +3.1; (KP 2.1): -0.78, +0.78; (KP 3.1): -0.4, +0.4; (KP 4.1): -1.57, +1.57; (KP 5.1): -3.14, +3.14.

Item MDA (mechanical diagram of the arm) specifies the mechanical diagram of the arm, and item CON (constraint) specifies the bounds of the change in the robot's generalized coordinates. [Note: KP stands for kinematic pair, and LI stands for link.]

We will specify the trajectory of the grip's motion in cartesian coordinates by a parametric dependence with the following form:

$$(1)\ X = B\ .\ P\ .\ \cos(A\ .\ P),$$

$$Y = B\ .\ P\ .\ \sin(A\ .\ P) + 1.2,$$

$$Z = 0.67,$$

which describes an archimedean spiral in a plane that is parallel to XOY and that is a distance of 0.67 m from it.

Figure 4 presents the results of plotting the program of the motion of a TUR-10 robot in generalized coordinates when the grip moves along trajectory (1) and when the parameter P changes from 0.0 to 60.0.

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UDC 51:681.3

Modeling Robot-Manipulators With Program Control

18610361b Kiev UPRAVLYAYUSHCHIYE SISTEMY I MASHINY in Russian No 1, Jan-Feb 89 pp 107-111

[Article by P. V. Gorshkov, A. V. Lyaletskiy, V. D. Frolov, and V. V. Yurchishin]

[Text] Introduction. This article describes the first version of a robot modeling system with program control. This system, the MRPU, was developed at the Theoretical Cybernetics Department of Kiev University. This system makes it possible, on the one hand, to assess the "viability" of the manipulation robot design that has been selected and, on the other hand, to automate the preparation of control programs for the manipulator.

Robot control languages—the high-level language UM and the low-level language AM—have been developed within the framework of the specified system. The language UM has been implemented by creating a UM-to-AM translator. The implementation of AM programs entails interpreting them to machine level by modeling the actions of robot-manipulators.

Formulation of the task. Any industrial robotics system contains the following:

—the robot itself (it is assumed that this robot is capable of effecting "elementary" movements in space and performing specified production actions);

—a computer system to control the robot;

—means of connecting the robot to the control system.

The development of each of the specified components is a complex problem that must be solved in an integrated manner since industry imposes strict requirements for computer resources and the time required for a robot to perform one action or another. The existing trends in the development of such systems assume, above all, researching their capabilities by modeling, checking the optimality of any decisions reached, and then linking them to a specific work environment.

In light of the aforementioned, the task of developing a system to model the actions of a robot-manipulator was formulated. Attention was concentrated on creating the algorithms and software required to control an arbitrary manipulator.

All means of controlling robots may be divided into two groups:

—means for planning and working out the robot's motion;

—means for planning and working out the robot's actions.

The first group contains means of planning a robot's trajectories and elementary movements from one specified point to another, which makes it possible for the robot to work out a planned (or previously known) trajectory. The class of tasks arising in the process is more or less defined, and in the simplest case most of them have a satisfactory solution. The second group consists of "adjustments" in the sense that they have practical value only in the case where the means belonging to the first group are present. It is assumed that they include methods of describing scenarios by using robovision and planning robot actions based on logical constructions and heuristic procedures for assembling complex objects from existing components, etc. Above all, however, they include language since all stages of "intellectualizing" a robot entail the tasks of communicating with and teaching the robot.

The simplest and easiest-to-implement languages are those that are geared toward direct specification of the robot's motion trajectory and that provide a mutually unequivocal correspondence between their statements and the robot's actions. Such languages belong to the class of low-level languages because, by analogy with existing standard assembler-type programming languages, their structures may be viewed as mnemonic codes of a robot's actions. The process of programming in low-level languages (which is generally implemented by using a training console) is tiring, demands a great deal of time, and frequently results in errors (the correction of which means repeating the entire programming process). For this reason, the next step was to develop a higher-level language by expanding the low-level language with standard structures of standard high-level programming languages and then including ways of making macros, apparatus for calling up subroutines, etc., in them.

Naturally, these languages reflect the fact that they are intended for programming the actions of robots. Several developments of languages for robots have been published previously.[1-3]

Architecture of the MRPU system. The MRPU system[4] is intended to model the actions of a robot that is controlled by using a high-level language. During the course of the modeling the systems uses and constructs a mathematical model of the robot-manipulator. This approach makes it possible, on the one hand, to estimate the "viability" of the robot-manipulator design selected (at the level of kinematic links, line lengths, mass, etc.) without resorting to a physical embodiment of the manipulator, i.e., it makes the MRPU system a CAD-type system. On the other hand (in view of the modular principle of its design), the system makes it rather easy to accomplish the task of "refining" the control means intended for a specific robot and makes it possible to

Figure 1. Architecture of MRPU System

Key: 1. UM program 2. UM translator 3. Mechanical and dynamic characteristics 4. AM program 5. AM interpreter 6. Data base 7. Planning and working out trajectory 8. Manipulator

concentrate efforts on creating the algorithms and software themselves and then testing it without involving the robot itself (Figure 1). The source data for the system are a program written in the high-level language UM (the UM program) and the kinematic and dynamic characteristics of the manipulator being modeled. We will note that a portion of these characteristics may be considered parameters of the UM program and that, after being analyzed by the UM translator, they are sent to the data base of the robot that is being modeled. The main function of the UM translator is to translate the UM program directly into a program in the low-level language AM (the AM program).

The AM interpreter is an interpreter of the statements of the language AM. Its primary purpose is to enable the manipulator to work out a movement from one point in space to another along a specified trajectory.

Information about the manipulator's kinematic and dynamic characteristics is formulated in the data base. This information about the number and lengths of links, types of connections, masses of the links, inertial moments, capacity of the drives, etc. (which is specified either by the user interactively or by default), is used to construct the motion laws and control over the manipulator's real movement. The Planning and Working out of the Trajectory block constructs a sequence of changes in the generalized coordinates transferring the manipulator's gripper from the initial position to the target position. This sequence is based on information input from the AM interpreter regarding the initial and target positions, orientation and approach vector of the manipulator's gripper, descent interval, and precision with which the gripper is brought into the vicinity of the target.

Classical theoretical mechanics methods describing the motion of solids have been proposed as the mathematical model of the manipulator. Some of these methods have been described previously.[5]

Work within the framework of the MRPU system has shown that these methods require the use of powerful computer resources, which is not always possible or economically justified. An original algorithm has therefore been developed to construct a mathematical model of a manipulator's movement with satisfactory time, capacity, and precision characteristics.

The Manipulator block implements the "real" movement of the robot-manipulator. This is accomplished either by obtaining information from the manipulator's "sensors" about its current position or by solving dynamics problems until it is modeled precisely.

We will examine the language for controlling the MRPU system, which constitutes its nucleus, in greater detail. To do this, we will first describe the system's environment.

Two finite-dimensional vector spaces are used in the environment of the MRPU system: the cartesian vector space (coordinates of cartesian points) and generalized vector space (coordinates of generalized points). Cartesian vectors are ordered sextets of real numbers. The first three numbers specify the point of a three-dimensional euclidean space, whereas the final three specify the orientation of a single vector at this point (which is interpreted as the orientation vector of the manipulator's end-effector). The cartesian space is introduced for convenience of programming and to help people comprehend the robot's actions. The robot itself actually functions in the generalized coordinate space. The dimensionality of the generalized coordinate space equals the number of links in the manipulator under examination. The cartesian and generalized coordinate spaces are related with one another by solving primal and inverse coordinate transformation problems for the specific type of robot. These problems play an important role in several methods of planning and working out the trajectory of robots' motion.

The environment of the MRPU system also uses an object called the local area, which is a coordinate system derived from the base system (i.e., that system to which the robot is "tied") by its parallel transfer along a specified three-dimensional vector with a subsequent turn at a specified angle around a specified axis. The local area is therefore specified in the form of an ordered group of four real numbers, the first three of which specify the transfer vector and the last one of which specifies the turning angle.

Language of the MRPU system. As has already been stated, the language AM is a low-level language, each statement of which specifies the "elementary" actions for the robot. AM makes it possible to use three types of data: integral, real, and vector. The vectors (points) may belong to the cartesian or generalized coordinate spaces. The language may have two types of statements—motions and references to peripherals (this includes statements referencing input and output peripherals and a pause statement). The motion statements are selected with an allowance for industry's existing requirements regarding software for manipulation robots. In the version of AM implemented, statements for movement along a straight line in the generalized coordinate space and along a straight line and circular arc in the cartesian coordinate space are identified.

It is clear that one necessary element during programming in the language AM is the input into the AM program (for example, from a training panel in the case where AM is implemented as the language of the control member) of the coordinates of all points in which the manipulator's end-effector should be and between specified pairs of which it should work out its required trajectory and perform the required production operation. It is often the case, however, that the coordinates of most of the required points are easily calculated on the basis of the coordinates of so-called reference points. The proposed version of the language UM was developed to make an allowance for this possibility.

The main purpose of the language UM is to make the process of programming the robot's actions in the cartesian space easier for the user.

Besides the types of data used in the language AM, yet another type is used in UM—logical data. As in standard high-level languages, arithmetic and logical expressions may be constructed over integral, logical, and real types of data. Expressions may also be constructed over vector, integral, and real types of data by using operations satisfying all vector space axioms. This makes it easy and simple to make calculations in vector spaces such as coordinate transformations. It should be noted that in the language UM there is a special assignment statement (in various modifications) for working with local areas that "takes" the process of recalculating the vector coordinates during the transition from one local area to another away from the user.

The statements of the language UM may be divided into three groups, i.e., those controlling the stream of calculations, the motion, and work with the end-effector. The statements that control the stream of calculations include traditional transfer, cycle, and assignment statements; compound statements; and I/O and subroutine call statements (including recursive).

The motion statements are the most important group of statements (indeed it is these statements that reflect the specifics of the language UM). Lying at the foundation of this group is the statement to move the manipulator's end-effector from the current position to a specified point. This statement may indicate the velocity of the

motion, the trajectory of the movement, and the orientation of the end-effector. Besides the motion statements, which are analogous to those in the AM, the language UM also contains statements for moving a specified distance along a specified direction, a statement for turning the end-effector a specified angle, etc.

The third group contains statements for bringing the end-effector to one of the required states (for example, active or passive for gripping) depending on the robot's specific working environment. This group includes statements specifying production operations.

As an example, we will use Backus normal forms to describe the transfer statement in the language UM (a complete description of this language has been presented previously[6]):

<jump statement>::=jump<identifier of object point> <orientation of end-effector> <route of movement> <orientation of end-effector>|<empty>ixed|[al]ong normal <route of movement>::=<empty>|[a]long straight|[al]ong-around-through <identifier of intermediate point>|[al]ong curve <name of curve of movement>

We will briefly explain the semantics of the proposed structures. The transfer statement specifies movement from one point in space (usually cartesian) to another. If the orientation is not specified in the statement, the end-effector is oriented randomly during the motion. Specification of a fixed orientation means that the motion will occur with the same orientation of the end-effector as at the initial point. Motion along the normal means an end-effector orientation during the motion that is perpendicular to the tangent in the plane of the curve (or a small segment of it) along which the movement is taking place. If the route of the movement is not specified, the transfer occurs along an arbitrary route (as a rule along a straight line in the respective space).

The following capabilities of the specified structures permit specifying the motion in cartesian space along a straight line and circular arc drawn through three points. Frequently encountered routes are entered into the route library. Each may be called up by name, which makes it possible to work out the required trajectory.

Features of implementing the language UM. There are two ways of implementing a high-level language: constructing an interpreter to interpret the statements of the language into the robot's actions and creating a translator from the language into a low-level language with subsequent interpretation of the latter.

The first method requires that the robot contain significant computer capabilities and rather extensive hardware, which has a significant effect on its cost. When the second method is selected, the robot may be less "intelligent" (and thus less expensive) but capable of working out the same program as in the first case. Furthermore, implementing a high-level language by translating it makes the language more flexible and independent of a specific robot than during interpretation (which is particularly important when developing modeling systems). The second method was therefore selected in implementing the high-level language in the MRPU system.

The language UM was implemented by using the previously described method of designing program systems.[7] First, an internal representation of the algorithms was selected that specifies the connection between an analysis of the source program and a synthesis from the internal representation of the AM program.

As a rule, the first stage in implementing any language is the analysis stage. This stage entails conducting a syntactic analysis of the source program, neutralizing errors, and creating an internal representation. Powerful and convenient means, i.e., the LEX lexical analyzer generator[8] and the YASS compiler compiler[9], were used in implementing the analysis stage.

To make economic use of the memory, the analysis is conducted in two stages. The first stage consists of the syntactic review of the source program with the allocation of all identifiers and values into sufficiently large auxiliary files. The program itself is coded in some numerical file. After this the exact sizes of the data sets formulated are known. They include scalar constants and variables and vectors representing cartesian points and generalized spaces as well as local areas.

In the second stage, a special table with the required size that is filled on the basis of the previously constructed auxiliary tables is allocated for each such set. All sets are accessed through global indexes, and information about all data is collected in a special data table. During the analysis process, expressions are first represented in treelike form. After each expression has been analyzed, it is transformed and rewritten to the form of the related internal representation. The memory allocated under auxiliary files is freed. An internal representation of the program, which is continuously coded in an integral file, is formed as a result of the analysis of the statement portion of the algorithms.

The following message is output for all errors discovered during the analysis (operands that are inadmissible from the standpoint of form and type for various operations, incorrect transforms, incorrect use of data types and classes, etc.):

error during analysis: <line number> <content of error>

Each error is localized. When errors are present in the analysis stage, no transition to the second stage (i.e., synthesis of the AM program from the internal representation) occurs.

The AM program is synthesized by bypassing the file of the internal representation, followed by the subsequent pseudoexecution of all of the statements. The internal representation of the program is coded continuously. Thus, all the statements (except the motion statement) are executed sequentially in a pass through the file. Once a section has been passed, it can only be returned to in the cycle. All expressions and vectors representing the coordinates of the points are calculated, and the statements controlling the calculation stream are executed when the AM program is synthesized.

The motion statements in the language UM are compiled in a sequence that specifies all of the movements made by the manipulator's end-effector during the process of the program's execution. The specified sequence is the AM program. Execution time errors (inadmissible index expressions, inadmissible assignments, transform errors, etc.) are also possible in the synthesis stage. Information about them is also output to the user; however, the synthesis process continues. The user himself may then decide whether the program synthesized is satisfactory and can trigger its subsequent interpretation.

The AM program is thus a protocol for the pseudoexecution of the UM program.

Structure of the UM interpreter. We will note that using modeling systems to demonstrate the movements of a manipulator based on the software developed has been examined in a number of works.[10]

Implementation of the AM program entails interpreting a robot-manipulator that has been specified interactively. At the beginning of such an interpretation, a mechanical diagram of the manipulator is automatically "compiled" on the basis of user-specified data. Next, the required trajectory of motion from point to point is planned and worked out. The process of moving in one of three principal planes in a cartesian coordinate system (selected by the user) may be observed on the screen of an ordinary display. Besides geometric information about the motion, information about the motion's characteristics (time, distance to the target point, status of the end-effector, etc.) is also output onto the screen.

A documentation mode in which all information (including "illustrations") is entered into a special file is also provided during the interpretation.

The MRPU system provides modes that permit the following:

—executing one and the same AM program (produced once after translation from the UM program) in different robot models;

—translating and executing different UM programs in one specified manipulator diagram;

—repeating the cycle of adjusting the model and translating and executing the source UM program.

Conclusion. Experiments conducted with the MRPU system have shown its positive aspects when modeling so complex an object as a manipulator, in which case only an ordinary display terminal is required. Of course, the task of "refining it" may require no less effort than the development of an MRPU system. However, it appears that such efforts will be purely technical in nature; for this reason, the latter task is not interesting from mathematical or programming standpoints.

A naturally expandable working version of the MRPU system has been implemented in the language C on an SM computer in the environment of a real-time operating system. Allowing for the overlay, about 80K of disk memory is required.

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Improving Methods to Determine Economic Efficiency of GPS

18610432 Leningrad SUDOSTROYENIYE in Russian No 2, Feb 89 pp 29-32

[Article by K. K. Beletskiy, V. M. Bukalov and V. N. Shevelev]

[Text] The renovation of the production capacities being developed in the country on the basis of advanced equipment, progressive technological processes and flexible production systems (GPS) requires considerable capital investment. The question of the economic evaluation of expedient measures being implemented which are faced by departments and enterprises that plan the introduction of the GPS production systems is especially serious. The gravity of the situation is due to the fact that until now the creation and introduction of GPS was, to a great extent, in the nature of an advertising campaign which presented GPS as a panacea capable of providing an industrial "breakthrough" to a new technical level. The contemplated measures were not supported by serious technical-economic analysis. The realization of the generated economically irresponsible plans for "gapization" led to a considerable number of unprofitable GPS. The ruinous consequences of trying to realize economically unsubstantiated ideas cast shadows on the very idea of creating flexible automatic production which, under conditions of changing enterprises over to cost accounting and self-financing, can threaten the discontinuance of work on creating better systems and installations, as well as the preparation of qualified personnel.

A necessary condition for fully economic independent enterprises to continue creating GPS on new higher technical and organizational levels is the skill and ability of the enterprise management to determine the strategy of the scientific-engineering development of a production system based on the economic consequences of the contemplated development.

Under such conditions it is of great importance to evaluate the expediency of the conducted measures, to identify and take into account factors that affect their economic efficiency, and determine the latter by taking into account these factors.

However, the use of existing general industrial methodology[1] to calculate the economic efficiency of the GPS, indicated the imperfection of the existing approach.

For this reason a number of organizations in machinebuilding sectors of the industry have developed specific features to determine the use of the GPS. Its use in a number of enterprises in the Leningrad region indicated that it needs further work.

Calculations of economic efficiency of GPS at the predesign and design stages, as well as at the introduction stage, should have the following goals:

—select the economically most efficient among alternative versions of the production systems;

—substantiate and form NIR [Scientific-Research Work] and OKR [Experimental Design Work] plans for the technical reequipment of machinebuilding enterprises under specific production conditions;

—substantiate the areas of technical-economic efficiency of GPS use and select an expedient version of its organizational form;

—calculate the actually achieved value of the economic effect as a result of the introduction of the GPS.

The basic principle of technical economic substantiation in creating and introducing the GPS is to obtain a national-economic effect. This means that it is necessary to select, from the best possible versions from the general-state viewpoint, systems of target indicators for a plan of economic and social development. In evaluating the efficiency of the design solutions for creating and introducing the GPS, it is necessary to take into account the basic consequences of their realization for the enterprises (organizations that develop and and manufacture GPS components, as well as those that introduce the GPS, including the technological preparation of new products.)

It is also necessary to utilize for the entire national economy a single norm coefficient of economic efficiency of capital investment, a single norm coefficient of the efficiency of labor resources and a single system of prices in technical-economic calculations in determining the efficiency of creating and (or) introducing GPS. It is expedient to calculate the economic effect not only for each year, but also for the entire estimated period including, as a rule, the development, technological preparation for production, assimilation and series production of GPS components and their effective service

life at machinebuilding enterprises. It is necessary to take into account fully the most significant expenditures and results on the basis of coordinated norms, not permitting repeated counting, with structural and time correlation of all counted components and results.

In the course of the analysis it is necessary to evaluate the practical implementation of the best GPS version by identified national economic criteria, keeping in mind the specifics of the national economic mechanism and the cost accounting interests of individual enterprises and organizations in the industrial sector.

A comprehensive technical-economic analysis should be provided with the selection of a comparison base that would satisfy the target and the structural and time comparisons of the GPS versions.

The comprehensive analysis being made consists also in that technically-economically substantiated GPS have all kinds of effects, achieved due to the realization of comparable design versions.

The economic efficiency of the GPS is determined first, by increasing the level of automation and the organization of production processes and, secondly,by the flexibility (readjustability) of these systems when products are changed.

The basic sources of economic efficiency of GPS are:

—higher productivity of equipment as a result of maximum utilization of its technical possibilities, an increase in the machine time coefficient (including due to no overlapping of auxiliary time),i.e.,

—an increase in the number of shifts in which the equipment operates and, therefore, a relative saving in capital investment;

—higher productivity of labor due to replacement of manual and machine-manual labor by automation (in basic and auxiliary operations), a reduction in the labor time and freeing workers;

—a reduction in readjustment time in the production process when products manufactured in the GPS are being changed;

—a reduction in the size of lots, the length of the production cycles and, as a result, the size of equipment due to uncompleted work;

—reduction in the time and cost of technological preparation for production with a high degree of continuity of tools and labor and technological processes;

—an increase due to automation of the stability of technological processes and a reduction in scrap.

It is well known that the basic (criterion)indicator of economic efficiency of any design solutions is the economic effect—an excess of results above costs. An analysis of GPS design versions and the realization of the most profitable of them, according to the criterion of the maximum economic effect, will increase the growth of the net production of sectors that are introducing the GPS, the consumer sectors and the income of the national economy as a whole. The simplest modification of the maximum economic criterion (for a similarity in results of creating and introducing GPS in comparable versions) is a minimum of normalized expenditures on a fixed result.

Normalized expenditures are usually the sum of the net cost and the norm effect of capital investment:

$$Z_i=C_i+E_{nc}K_i \quad (1)$$

where Z_i are normalized expenditures to make products for the i-th version of creating and (or) introducing GPS, rubles; C_i is the cost of production for the i-th version of the GPS, rubles; K_i is the capital investment (NIR, OKR, technological preparation, acquiring necessary production means, assimilation and production) for the i-th version of the GPS, rubles; E_{nc} is the norm coefficient to compensate for capital investment, adopted at present equal to 0.15.

The most economically advantageous version of a GPS is a version corresponding to a minimum of normalized costs among all compared versions.

In practice very frequently it is simplest to obtain not the absolute values of production cost C_i and capital investment K_i, but data on their changes in two comparable GPS versions with an equal production result. Formula (1) in that case assumes the form

$$E=\Delta C-E_{nc}\Delta K \quad (2)$$

where E is annual economic effect of using GPS with respect to production output in an existing production enterprise or another GPS version (with a similar production result),rubles;

$$\Delta C=C_1-C_2 \text{ and } \Delta K=K_2-K_1$$

The formula structure of normalized costs and annual economic effects was formed when only capital investment was limited[3]. Actually this refers not only to the capital investment, but also to labor resources, scarcity of mineral deposits and, therefore, to several kinds of raw materials and other materials and power fuel resource. Since a change in traditional production systems to flexible ones does not lead to palpable changes in the consumption of raw and other materials and fuel power resources per unit of manufactured product, it is

very important in the formulas of normalized cost and effect, to take into account feedbacks in the national economy which originate with additional attraction of labor resources or, conversely, freeing scarce labor resources due to the implementation of these or other design versions of production systems.

This provides a basis for writing the formula to determine the economic effect in the form

$$E=\Delta C-E_{nc}\Delta K \text{ plus or minus } E_{nl}\Delta N \quad (3)$$

E_{nl} is the norm of economic effect of labor resources; ΔN is the average annual number of additionally used (at "minus" sign) or freed ("plus") workers in enterprises which introduce GPS.

Values of norms E_{nc} and E_{nl} have no strictly scientific substantiation at present. A method proposed by L. V. Kantorovich[4] to determine them can be used. However, in this case, planned compound material-financial and labor resources of the country should be kept in mind. When there is no data on the average annual cost of fixed production, capital norms established in methodologies[1,2] can be used in new estimated costs.

In view of the fact that the creation of a GPS is not a one-time measure but a strategic direction of developing production bases of enterprises [1], the evaluation of GPS by the economic effect criterion according to formula (3) is not significant in many cases because it does not take into account the results of further development of the system.

The basic correlating indicator of economic efficiency in creating and (or) introducing the GPS is an internal economic effect during the estimated period, determined by the following formula:

$$Э=\sum_{t=1}^{T}\{[\Delta И_t+\Delta P_t+E_{н.т}\Delta Ч_t+E_{н.к}(\Delta K_t-\Delta Л_t)+\Delta У_t](1+E_{н.п})^{-t}-E_{н.к}\Delta Ф_{T+1}(1+E_{н.п})^{-T-1}\}. \quad (4)$$

Here Δ is the difference between corresponding parameters in t-th year of estimated period T, for example, $\Delta I_t=I_{1t}-I_{2t}$. In this case, I_{1t}, I_{2t} are current net expenditures without taking into account amortization deductions for full restoration (renovation) and expenditures for all kinds of repairs of fixed capital; R_{1t}, R_{2t} are expenditures for repairs of fixed capital (current, medium, capital); N_{1t}, N_{2t} average annual number of workers; K_{1t}, K_{2t}—capital investment; L_{1t}, L_{2t}—liquidation balance of worn-out fixed capital; L_{1t}, L_{2t}—damage to consumers due to lack of products; $F_{1(T+1)}$, $F_{2(T+1)}$—residual cost of fixed capital operated during period following estimated period; S_p—norm of reducing the expenditures at various times to a single one (in the given case to "zero" or "start") year of the estimated period.

The technical-economic substantiations of creating and introducing GPS for new enterprises being built must take into account additional costs related to regional differences in providing workers with a social infrastructure (housing, schools, hospitals, nurseries, cultural and educational establishments, municipal facilities), the costs of moving workers (and their families)into the new region as well as maintaining them. Keeping in mind regional differences does not change the form of expression (4) being reflected only in the value of the effect (Table).

Capital Investments, Current Expenses and Costs Related to Attracting Labor to New Regions, Thousands of Rubles/Man [5, p.500]

Region	Capital investments: Into social infrastructure	Capital investments: For maintaining workers (increase as compared to the basic region)	Capital investments: For moving workers and their families	Current expenditures: Of social infrastructure	Current expenditures: For maintaining workers (increase as compared to the basic region)	Calculated expenditures
Far North	34.0	2.4	2.5	4.1	0.4	10.3
Central Siberia and Baykal-Amur zone	23.0	1.6	1.7	2.8	0.3	7.0
Moscow oblast	10.0	—	—	1.2	—	2.7

At enterprises already in operation, costs of the social infrastructure can be taken into account in the technical-economic substantiation of the GPS only when determining the cost accounting, but not the national economic effect and only if the workers freed by the GPS used the service area and other facilities of the enterprise infrastructure.

The selection of the most economically efficient versions of the production system is based on using the target function of the integral (4) or annual (3) economic effect. However, use of these criteria when comparing versions is permitted only when the versions have similar national economic results taking into account social consequences in the realization of the design solutions.

When versions of production systems are compared taking into account unequal social effects, in most cases it is possible to use the following approach. Potentially

possible GPS versions and facilities for their introduction are selected, each one of them satisfying social standards (i.e., given levels of reaching target indicators), and they form a totality of socially acceptable versions. Then from this totality the most advantageous version is selected using the criterion of maximizing the integral or annual economic effect.

Obviously the introduction of limitations on various parameters that reflect on the social effects of GPS, not reduced to monetary terms, contradicts the requirement of maximizing national results. Part of the limitations, for example, that characterize national economic damage as a result of failures of production systems can be transferred to the target function and taken into account in the integral (4) economic effect. However, some indicators that reflect the level of the effects of various forms of production systems on social efficiency cannot, at present, be evaluated convincingly in monetary terms.

In actual situations when, besides economic consequences of realizing versions of production systems, it becomes necessary to take into account some one indicator or social effectiveness that cannot be expressed directly in monetary form, the following approximate procedure can be used[5]. Let an increment of capital investment from K_1 to $(K_1+\Delta K)$, annual costs from C_1 to $(C_1+\Delta C)$ and number of personnel from N_1 to $(N_1+\Delta N)$ cause an increment of some social effect from S_1 to $(S_1+\Delta S)$. To bring the versions to a similar result it is necessary to correct the indicators as follows:

$$K_1\ S_1+\Delta S/S_1;\ C_1\ S_1+\Delta S/S_1;\ N_1\ S_1+\Delta S/S_1.$$

Using the formula of deduced costs, it is possible after conversion to obtain a condition of economic benefit of additional costs ΔK and ΔC and the additional attraction of labor forces ΔN to obtain an additional social ΔS:

$$\Delta C+E_{nc}\Delta K+E_{nl}\Delta N/\Delta S \text{ less than or equal to } C_1+E_{nc}K_1+E_{nl}N_1/S_1. \quad (5)$$

Condition (5) shows that to adopt a version with great social effect, it is necessary that the ratio between the cost increment and the social effect be no greater than the cost of the replaced (basic) version.

When studying the initial data needed to determine the effectiveness of creating and (or) introducing the GPS, two characteristic situations can be distinguished. The ideal situation originates when the solutions are implemented with the full determination of the initial data. The technical-economic substantiation is done basically on the basis of the determined conception of the maximum economic concept. Under actual conditions, however, situations arise when, to each version of the production stem, there may correspond a multiplicity of consequences or results. Such situations arise, in particular, from the above-mentioned multicriterion presentation of the problem and interval evaluations of various parameters involved in the criterial expressions.

To select solutions when ambiguities exist, methods of the statistical solutions theory[6,7] are used. In determining the expected economic effect of creating, introducing and further developing the GPS it is proposed to use the criterion known as Gurvits's criterion since it permits maximum utilization of experience in designing to determine probability values of the realization of the estimated economic effects at various stages of development and introduction. Gurvits's criterion has the following form:

$$E_o=P_FE_{max}+(1-P_F)E_{min}, \quad (6)$$

where E_o—expected economic effect of creating and (or) introducing the GPS; E_{max}, E_{min}—corresponding to the greatest and smallest possible values of the expected effect, determined by taking into account the spread of individual parameters to calculate capital investment, current expenditures and deduced costs; P_F—adduction coefficient of preliminarily calculated indeterminate effect on what was actually expected. Depending upon the stage of design of the production system for which the economic effect was calculated (corrected, approved), the probability P_F of coincidence of the actual economic effect with the maximum calculated one, according to [7 p.48] is as follows: 0.3-0.55 with technical-economic substantiation, 0.45-0.65, for a preliminary design, and 0.55-0.75 for a technical design; when developing working documentation for an experimental design—the figure is 0.7-0.85 and for an installation series, the figure is 0.85-0.82.

Conclusion. The directions proposed in this article for the development methods to determine the economic effectiveness of the GPS make it possible, on one hand, to expand the sphere of economic analysis including the determination of the most effective directions for developing production systems by determining their integral economic effect while, on the other hand, to increase the authenticity of the obtained evaluations as a result of taking into account the effect of reducing labor resources, the many criteria of the problems being solved and the indeterminacy of the initial data which is especially important at various stages of selecting directions for developing production systems.

Footnotes

1. In 1987, 403 rapidly readjustable flexible technological systems were installed in industry, as were 15,000 NC metal-cutting machine tools, 484 rotor and rotor-conveyer lines; 10,000 industrial robots (ARGUMENTS AND FACTS, 1988, No 37).

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'A Walking Wheel'

18610440a Moscow PRAVDA in Russian 1 Feb 89 p 2

[Text] Minsk 31 Jan (TASS). Experts regard the wheel as an ingenious human invention. Yet, exploring and innovative minds are constantly working to improve it.

V. Ishchein, a staff member of the Belorussian Polytechnic Institute, has developed a wheel which can both roll and walk, if necessary. His brainchild can be described as four criss-crossed legs with rubber shoes. This mechanism was attached to an engine block made by the Minsk Tractor Plant and performed miracles. During the testing, the minitractor with a truck simply walked over the curb—an obstacle to a regular wheel. Then it walked back and forth on loose soil several times. In so doing, it did not get stuck and did not leave a print in the soil. While on solid ground, the tractor driver virtually did not feel any vibrations which in the past, have prevented similar designs from finding practical uses.

In the expert's opinion, V. Ishchein's wheel is suitable for use in all-terrain vehicles, amphibious vehicles, tractors, and other agricultural machinery. A robot with such a running gear could climb stairs, e.g., to a nuclear reactor. The "walking wheel" can be used on motor carts for disabled persons.

Yet, the industry is in no rush to implement this novelty which has been successfully demonstrated at many exhibits: too much trouble with retooling. Yet, it was appreciated by one of the branches of the USSR Academy of Sciences. It is financing the development of a new walking wheel design for robots.

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